SCIENTIFIC AMERICAN
No. SUPPLEMENT 679

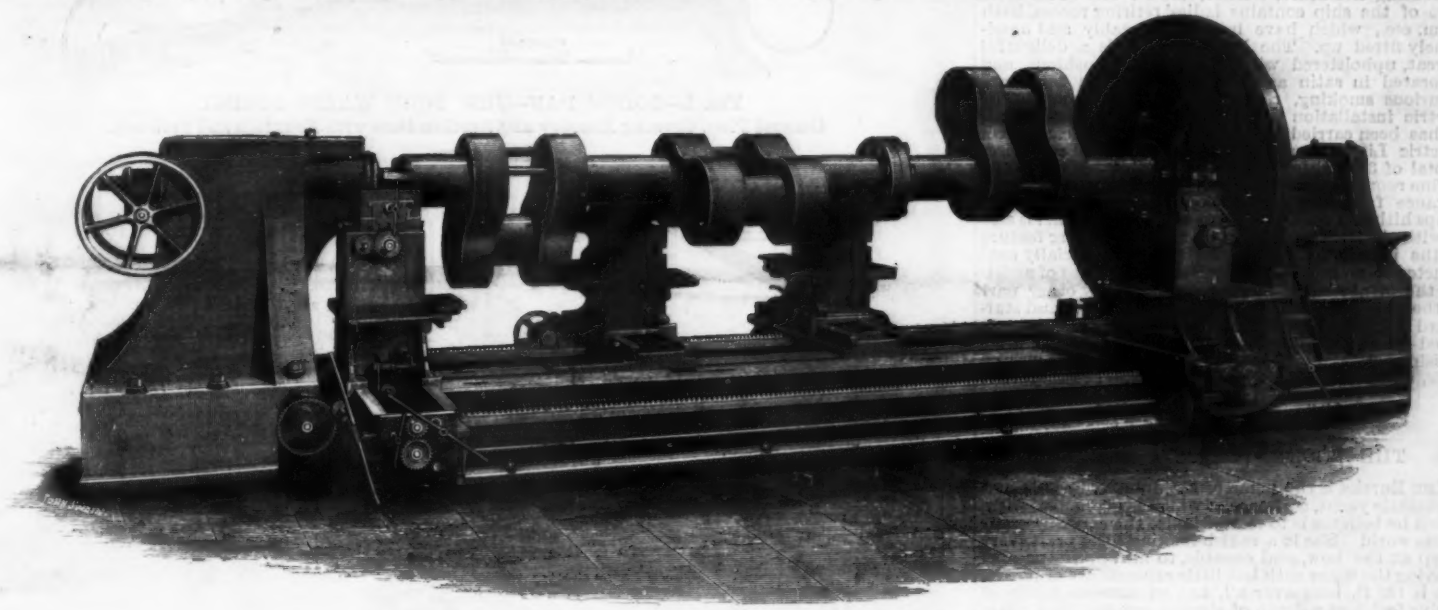
Scientific American Supplement, Vol. XXVII., No. 679.
Scientific American, established 1845.

NEW YORK, JANUARY 5, 1889.

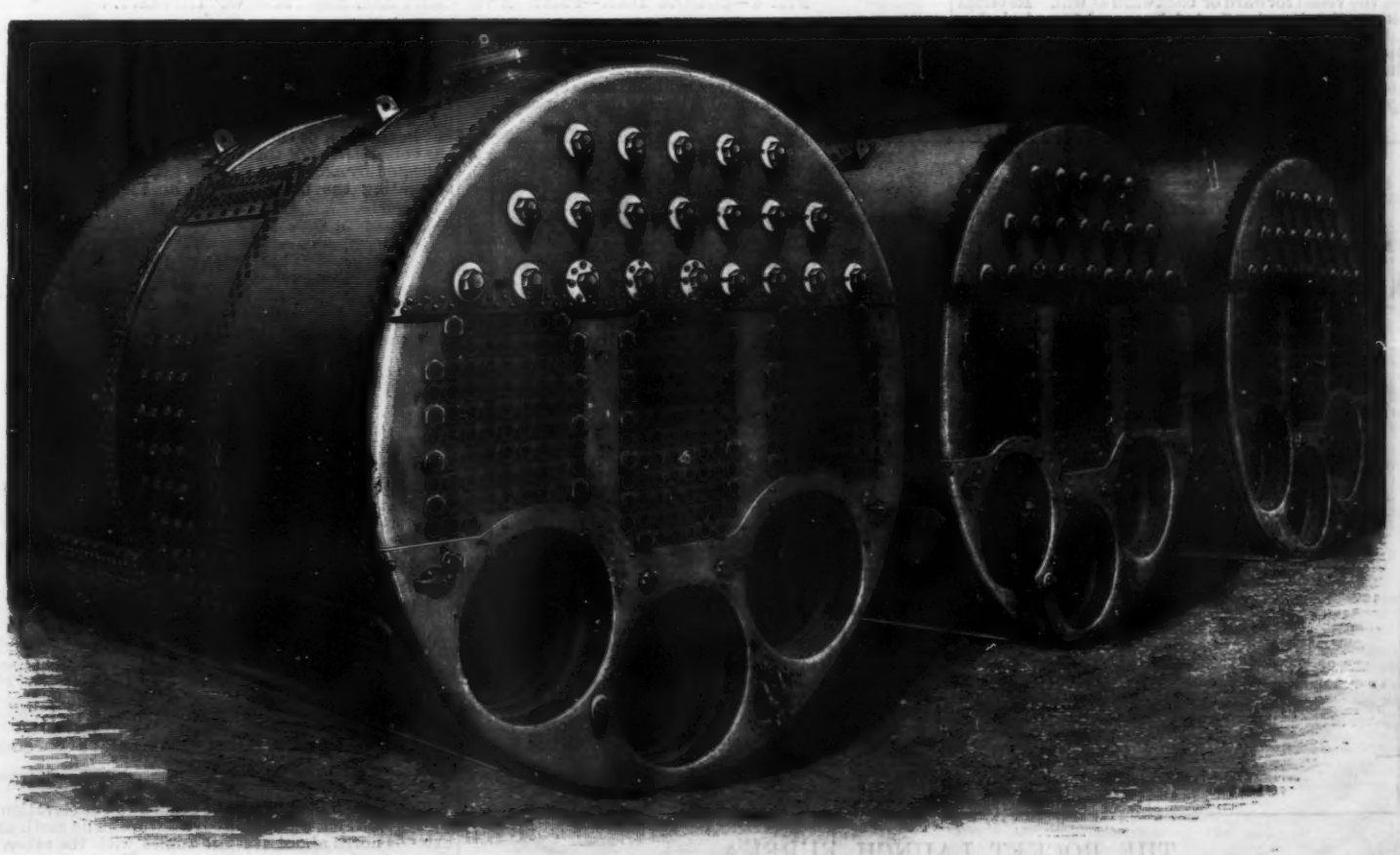
Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.

## ROYAL MAIL STEAMSHIP ROSLIN CASTLE.

THE Roslin Castle, the boilers and crank shaft of which we illustrate, is the largest vessel of Sir Donald Currie's Castle Royal Mail Packet Company's fleet, which trades between London and the Cape and other African ports. The vessel has recently been lengthened, and her engines have been tripled, while the whole of the old stern has been cut off, and a new one having finer lines, and giving a much freer run, has been built on, the result of all of which will be, it is hoped, a very considerable acceleration of speed. The alterations to the vessel having been intrusted to the Hartlepools, the Roslin Castle was sent there some six months ago, and placed in the hands of Messrs. Edward Withy & Co. and Messrs. T. Richardson & Sons, and within the last few days these firms were enabled to steam the vessel round to London, in order that she might be finally made ready for her voyages. The old engines had cylinders of 50 in. and 90 in., with a 60 in. stroke, and had a coal consumption of 1·9 lb. per horse power per hour, and the new triple engines are 36 in. + 60 in. + 96 in. with a 60 in. stroke. The engines have been tripled by the adding of a new high pressure engine complete to the forward end of the original compound engine, and by the replacing of the original cylinders by new intermediate and low pressure cylinders of suitable diameters. The valve casings of the high and intermediate pressure cylinders have been placed at the back, and the valves of these two cylinders are worked by Wylie's patent gear. The valve of the low pressure cylinder is worked by the original link motion. By means of this arrangement the length of the new tripled engine exceeds by very little that of the original compound engine. The crank shaft which we illustrate chucked, ready for turning in Messrs. Richardson's great lathe, is 18 in. diameter, and weighs some thirty tons. The original low pressure length was retained, and part of the high pressure length—now the intermediate—up to the forward crank cheek. The part of the crank shaft forward of this is entirely new and has been shrunk into the old crank cheek. The forgings were all made by Messrs. T. Richardson & Sons, and, when completed, the whole length of crank shaft was bolted together, and received the finishing cut in the lathe. The boilers are three in number, having eighteen furnaces—Fox's corrugated. They—the boilers—are 14 ft. 4 in. mean diameter, are 17 ft. 9 in. long, and constructed for a working pressure of 160 lb. While Messrs. Richardson & Sons have been busy with the engines, Messrs. Withy & Co. were occupied with the hull. The stern of the ship, as originally built, was considered too full. It has been now completely cut away for 45 ft., and a new stern of 60 ft. has been



CRANK SHAFT, STEAMSHIP ROSLIN CASTLE.



BOILERS OF THE STEAMSHIP ROSLIN CASTLE.

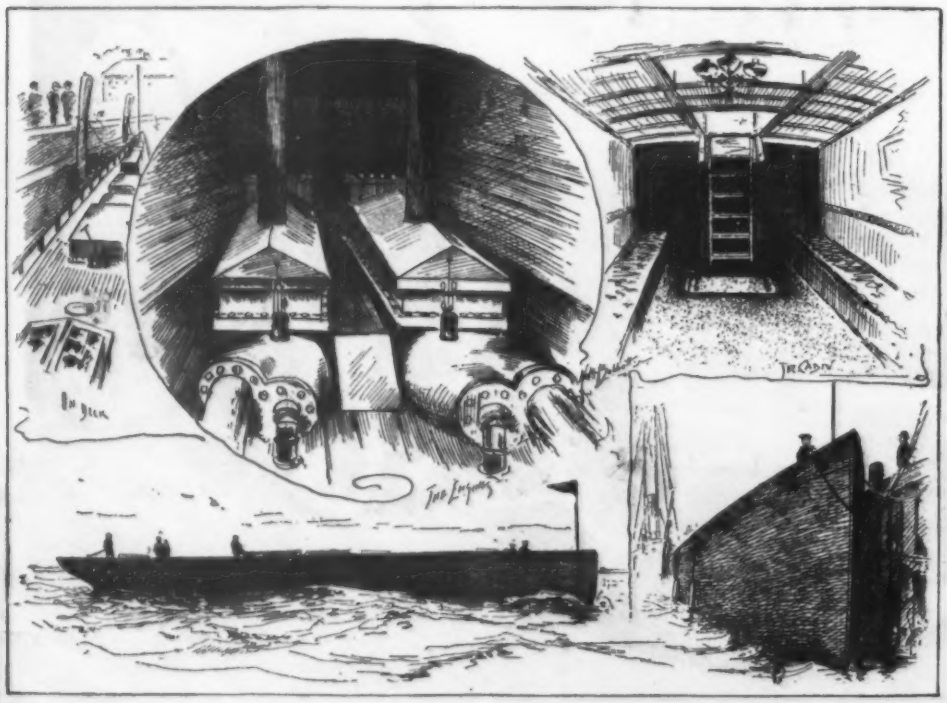
built on. The run aft is now much finer, and the result is considered in every way satisfactory. The dimensions of the vessel are now: Length over all, 410 ft.; beam, 48 ft. 9 in.; moulded depth, 31 ft. 6 in.; and a mean loaded draught of 25 ft. 8 in.; the gross tonnage being about 4,400. The Roslin Castle previously attained an average speed of 12½ to 13 knots at sea, but it is now hoped that, owing to her increased power and finer lines, she will maintain an average of 15½ knots. On the run from Hartlepool to London the speed could only be taken for two hours, owing to the thick fog during the remainder of the run. During these two hours the speed was at the rate of sixteen knots, thus giving every indication of coming up to the anticipated speed when in ordinary work at sea.

The vessel has accommodation for 168 saloon, eighty-four second class, and seventy-two third class passengers, and carries a crew, including four deck officers and seven engineers, of 120 hands all told. The various state rooms and private cabins are handsomely fitted up and the saloon is a remarkably elegant room, being artistic and cheerful. In the skylight turret of the saloon are portraits on satin wood, painted by hand, of Mozart, Watt, Humboldt, Spencer, and others, representing literature, science, music, etc. The after part of the ship contains ladies' retiring rooms, bath room, etc., which have been comfortably and handsomely fitted up. The ladies' boudoir is a delightful retreat, upholstered with most inviting cushions, and decorated in satin and cedar woods, and there are luxurious smoking, reading, and music rooms. The electric installation is one of the most complete afloat. It has been carried out by the Anglo-American Brush Electric Light Corporation, of London, and comprises a total of 360 lights throughout the ship. Even in the engine room the hand lamps used are electric—a vast advance from the old smoky, clumsy, and dirty oil lamps hitherto used. The propeller shaft tunnel is also lit with electricity; and another distinguishing feature of the installation is an electric lamp specially constructed to go into the water, for the purpose of assisting the inspection of the propeller, or any other part of the ship below the water line. The port and starboard lights are electric, and search lights are also provided for use when entering narrow channels or when cruising. Portable lights are also ready for use on deck, and in the holds when necessary.—*The Engineer.*

## THE ROCKET LAUNCH EUREKA.

THE Eureka is the name of Mr. John A. Secor's new pneumatic yacht, a picture of which is given herewith, which he believes is to revolutionize the carrying trade of the world. She is a rakish-looking little craft, very sharp at the bow, and capable, to all appearances, of cleaving the water with but little expenditure of power. She is 100 ft. long over all, has an extreme width of twelve feet and a depth of six and one-half feet. Her draught is four and one-half feet aft and three feet forward. Displacement about sixty-five tons. A bulkhead divides the vessel amidships. The bow is tastefully fitted up as a cabin, and the machinery is placed aft, immediately against the rudder post, and does not take up more than twelve square feet.

This new machinery is unique both in construction and design. In Mr. Secor's system the propulsion is effected by the direct reaction against the external water of the gaseous products of successive explosions of fuel gas and air issuing from submerged tubes. The machinery consists of a series of heavy steel cylinders, the ends or muzzles of which are open and in direct contact with the water surrounding the vessel. These cylinders contain no internal machinery whatever, but are filled with air and any inflammable gas or hydrocarbon exploded by the agency of electricity, and which forces the vessel forward or backward at will. Reversal in either direction is effected by opening and closing suitable gate valves at each end of the cylinders. The continuity of action is obtained by means of a number of chambers, from which the discharges occur, not simultaneously, but in well defined rotation.—*New York Graphic.*



THE ROCKET LAUNCH EUREKA.

## SODOM DAM—NEW YORK WATER SUPPLY.

THE Sodom dam, now being built by the Aqueduct Commission of New York to impound the water of the east branch of Croton River, will add some 8,000,000,000 galls. to the supply available during dry seasons. The water will flow to Croton dam and enter the aqueduct through the gate house, which we illustrated and described in a recent issue. The reservoir at Sodom will be formed by two dams, a masonry one 88 ft. high 12 ft. wide at the top, 47 ft. thick at the bottom, and 500 ft. long. The foundation for this dam will be carried down until seamless rock is encountered, recesses being cut in the rock of the hills to receive the ends. During the construction of this dam the course of the stream is deflected by a crib dam. At the eastern end is a low hill separating the masonry from an earth dam having a rubble core. This hill will be graded to the elevation of tops of both dams, 425 ft. above datum. The earth dam extends north about at right angles with the other, as shown on the accompanying map. North of the earth

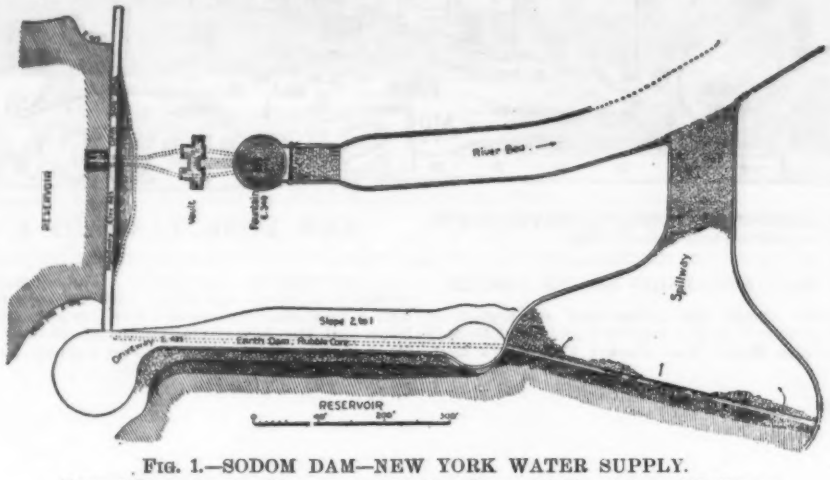



FIG. 1.—SODOM DAM—NEW YORK WATER SUPPLY.
General Plan, showing Masonry and Earthen Dam with Fountain and Spillway.

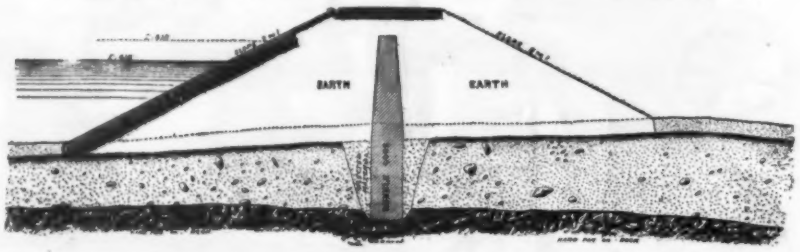



FIG. 3.—SODOM DAM—CROSS SECTION OF EARTHEN EMBANKMENT.

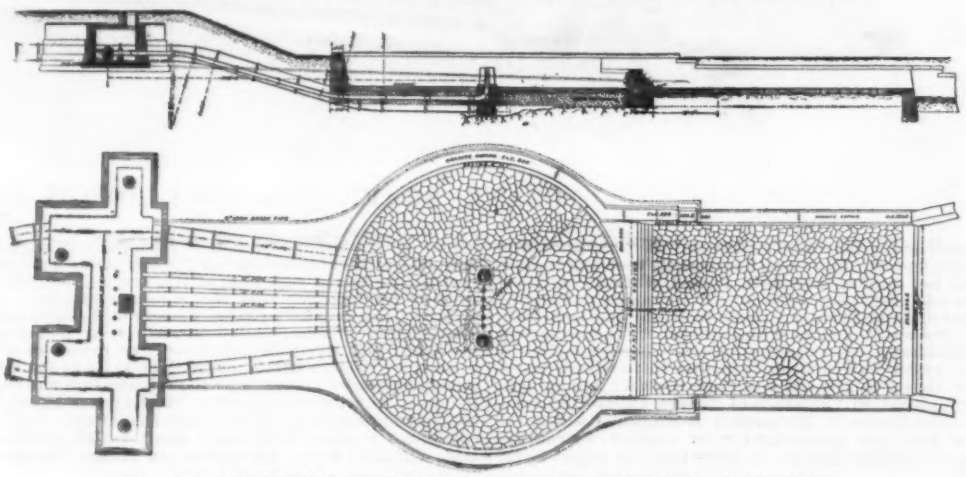


FIG. 4.—SODOM DAM—PLAN AND CENTRAL SECTION OF OUTLET.
Showing Flow of Water from this Reservoir toward Croton Dam. With Mains, Valve Chamber, Aerating Fountain, etc.

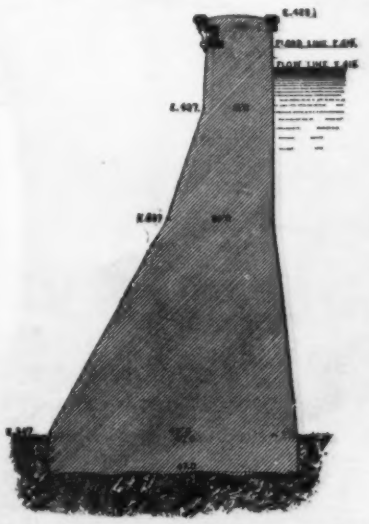


FIG. 2.—SODOM DAM—MASONRY CROSS SECTION.

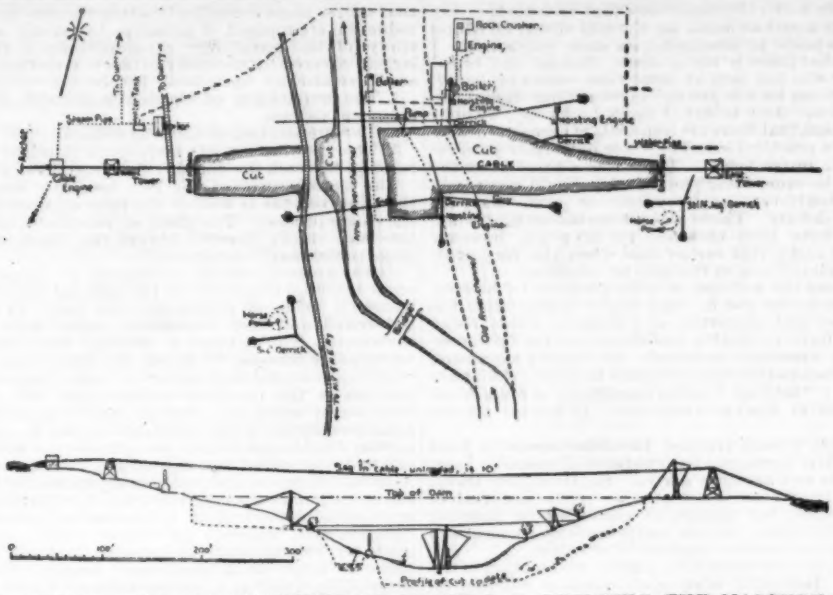



FIG. 5.—SODOM DAM—ARRANGEMENT OF PLANT FOR BUILDING THE MASONRY DAM.

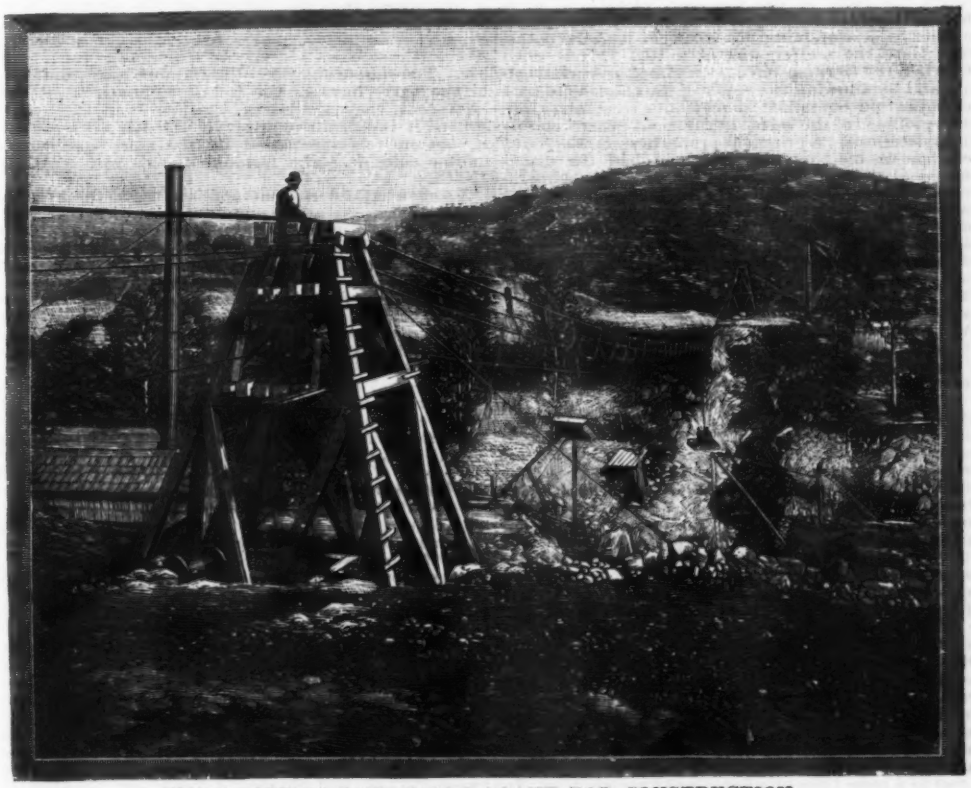


FIG. 6.—SODOM DAM—CABLE PLANT FOR CONSTRUCTION.

FIG. 7.—SODOM DAM—CABLE PLANT, FALL ROPE CARRIERS AND CHAINS.

dam is the overfall. Drawings of the section of both of these dams are presented.

The flow from the reservoir will be through two 48 in. pipes and five 12. in pipes leading to an aerating fountain located just below the masonry dam. (See Fig. 4.) The supply will be controlled by suitable valves in the gate house shown.

The arrangement of the plant for building the masonry dam is clearly shown in the annexed plan and elevation (Fig. 5), for which we are indebted to the courtesy of Assistant Engineer Walter McCulloh. It is doubtful if a site possessing more physical adaptations to the cable system of handling material could be selected than that of this dam. The hill at each side rises to a height sufficient for the cable to clear the top of the dam after the latter has been finished. On each hill is a frame tower (Fig. 6) in line with the center of the dam. These are placed 762 ft. apart. Stretched across the valley from tower to tower is a 2 in. solid center steel cable upon which runs a double trolly sheave secured in a rectangular iron frame, which is operated by an endless rope passing around one drum of the hoisting engine placed at the western end. The cable is held at each end by a log deadman sunk in a trench at right angles to the line.

The trench is excavated in solid rock, and the deadman is heavily loaded with live rock. To place the cable in position one end was made fast at the eastern tower, then to the opposite end was secured a chain which was passed over the second tower to the drum of the hoisting engine. By this means the cable was raised as far as the chain would allow and there held until a new hold could be obtained. The final tightening was done by turnbuckles after the end had been passed around the deadman and secured.

Running upon the cable is the carriage above mentioned. This is provided, in addition to the two trolly sheaves running upon the cable, with two others at the lower corners of the frame for handling the fall rope. The frame forms part of the circuit of a ⅝ in. endless steel rope which passes around an idle sheave at the eastern tower and four times around a concave friction winch drum of the hoisting engine. The endless ropes serve to move the carriage to any desired point on the cable. The hoisting rope is wound upon a grooved drum of the same diameter as the winch, 54 in. The rope passes over one of the lower pair of pulleys of the carriage, then around the pulley block, then over the other pulley and its end is made fast to the block. The hoisting rope is prevented from sagging by means of wooden blocks—fall rope carriers—riding on the cable and held from separating more than 25 ft. from each other by chains when the carriage is at the most distant point of its travel. The rope passes through openings near the lower ends of the blocks.

The engine is a double friction drum and link motion of 50 horse power, and is operated by five levers in addition to the throttle; the drums are mounted loosely upon the same shaft, to which motion is transmitted from the engine shaft by gearing. Either drum can be thrown into gear by means of a lever operating a friction clutch. A second lever, one for each drum, operates a brake band. The fifth lever controls a link motion for reversing. This makes the drums entirely independent of each other, and permits the hoisting or lowering of the load while it is being carried in either direction along the cable. The capacity of the cable is 20 tons.

The location of the derricks and their hoisting engines are shown in the plan. These act as aids to the cable, collecting the load to be carried away and distributing the material brought when its destination is outside the line of the cable. Stone is brought from the New York & New England Railroad over a track located about half way up the western hill.

The cable and engine were furnished and erected by the Lidgerwood Manufacturing Co. The dams are being built by Sullivan, Rider & Dougherty, the contract price being $450,000.

Heretofore this system of handling material, the invention of Milo W. Locke, has been used principally in quarrying. The above description shows its admirable adaptability to the handling of supplies and refuse in an engineering work.—*Engineering News.*

## ALUMINIUM.*

By HANFORD HENDERSON, Professor of Chemistry and Physics, Philadelphia Manual Training School.

IT is my purpose, this evening, to speak to you for a few moments on the subject of aluminium, an element whose name is to-day in almost everybody's mouth. You may have observed that in different mouths it has taken different forms. From some we hear of it as aluminum, while others are always careful to say aluminium. On grounds of both euphony and historic usage the longer name has, I think, decidedly the preference. The substance of the element, unfortunately, has not attained so common a currency as its name. It has been called, and not without propriety, "the metal of the future." There is a dual significance locked up in this designation. The metal is so almost noble in its qualities, so useful in application to the arts, and in all respects so much to be desired, that, as we wish all good things for the future, so we wish for it, aluminium. Had it been known in Sir Thomas More's time, it would undoubtedly have been the only metal used by the Utopians. But it is also the metal of the future in another and much less desirable sense. So persistently has it resisted the best skill of our metallurgic art, that it has taken some faith to believe that the metal would not always belong to the future and never to the present. However, ours is a progressive age, and the metallurgy of aluminium, though somewhat sluggish, does advance perceptibly. Our knowledge of the problem is to-day a little greater than it was yesterday. To-morrow, we may reasonably hope, will find our store of still better dimensions. The work of the past few years has been particularly encouraging. In calling your attention to this promising though somewhat elusive metal, therefore, I do so from a belief that the subject is one of growing importance, and will in time merit the share of interest you may bestow upon it.

You are acquainted, I doubt not, with the story of Tantalus. The position of the chemist in quest of aluminium is almost as unfortunate. The metal he

* A lecture delivered before the Franklin Institute, Monday, January 9, 1888.—*From the Journal of the Institute.*

seeks is all around him. He can scarcely move without treading on some of its compounds. Yet it eludes his eager pursuit, like some metallurgical will-o'-the-wisp. It recedes from his touch with almost the same persistence as the water and the fruit from the unhappy King of Phrygia.

Iron is the symbol of our present material civilization. It is among the most abundant of metals. It is, indeed, everywhere, for it is the great pigment of nature. It paints our sandstones brown; our bricks, red; and our clays, yellow. You can scarcely get out of the sight of it. But this comparatively new metal, aluminium, is even more abundant.

We do not know of what the center of our great whirling earth is made. As the globe, taken as a whole, is between five and six times as heavy as water, while the rocks open to our study are only about two and a half to three times as heavy as that standard, we may not unreasonably suppose the core to be composed of the heavier metals—iron, lead, zinc, perhaps silver, gold, and platinum. Of the composition of the surface of the earth, however, we have more definite information. Oxygen, the gas upon which life itself depends, makes up about one-half of these rocks; silicon, the basis of ordinary sand, about one-fourth; while aluminium stands third quantitatively in our recognized list of seventy odd elements. You see how relatively abundant this metal is in combination with other elements. And not only is there a great deal of it in absolute quantity, but the forms in which it occurs in nature are also correspondingly numerous.

Mineralogists have described and named nearly a thousand different minerals. In more than two hundred of these, aluminium occurs as an essential constituent. With many of its more beautiful forms you are doubtless familiar. It does not paint with the generous hand of iron, but it is a far more subtile colorist. There is scarcely a gem mineral, outside of the diamond and the rock crystal, that does not contain aluminium. The brilliant sapphire is an oxide of the metal. Of similar composition are the oriental ruby, the oriental topaz, and the commoner form, corundum. Add a little iron to this, and we have the valuable abrading material known as emery. The real ruby and the much prized gem alexandrite are compound oxides of the metal. Among the silicates it occurs in nearly all the known varieties, from the common clays and other rock-forming aggregates to such royal gems as the emerald, the garnet, the lapis-lazuli, the party-colored tourmalines, and the topaz. As a hydrous phosphate, it gives us the turquois, one of the most beautiful among the mineral blues.

I had in my possession at one time a very interesting ring. The band was made of aluminium, and displayed a fine oriental ruby, thus illustrating to excellent advantage the appearance of both the metal and its oxide.

These treasures, however, constitute a very inconsiderable part of the earth's surface. It is made up, for the most part, of much commoner stuff, and it is with this that the metallurgist has to deal. Of the many forms of mineral compounds in which aluminium occurs, there are but four which are at present made the subject of his skill. These may properly be termed ores of aluminium. They are: corundum, the common oxide, which occurs in some plenty in the mountains of western North Carolina; cryolite, the double fluoride of aluminium and sodium, which is brought to Philadelphia by the shipload from Arksut Fiord, in Greenland; beauxite, the hydrated oxide of aluminium and iron which occurs abundantly in Southern France; and kaolinite, or common clay, the silicate of the metal, which is found almost everywhere.

In nearly all of the older rocks we find an appreciable amount of gold. In the soils derived from the disintegration of these masses, the same precious metal is to be found. Some one has taken the trouble to calculate that the clay underlying Philadelphia contains at least $15,000,000 worth of gold. But as it would take many times this sum to effect its extraction, the metal is likely to remain where it is. No one, I believe, has had the courage to calculate the value of the aluminium contained in the same clay beds. I shall not tax you with such a calculation, but I will ask your patience with a few figures that I have used for a less extended computation. I believe that they will do more than anything else I can say to impress you with the commercial value of the metal and the present state of our chemical knowledge concerning its extraction. I am going to ask your attention, not to the vast amount of clay underlying our city, but to a single cubic yard of that material. I give the calculation in detail, believing that some of you who are not familiar with such processes may not find it uninteresting.

A cubic foot of water weighs approximately sixty-two pounds, consequently a cubic yard of that fluid will weigh 1,674 pounds. The specific gravity of clay may be taken at 2·5. The weight of a cubic yard of clay therefore would be two and a half times the weight of the same volume of water, or 4,185 pounds. There is about forty per cent. oxide of aluminium in ordinary clay and about fifty-six per cent. of metal in the oxide, so that a cubic yard of clay contains about 937 pounds of metallic aluminium. At $12 a pound, an average price, this is worth over $11,000.

This result is rather surprising. Let me repeat it. One cubic yard of ordinarily pure clay contains an amount of aluminium for which society is willing to pay over $11,000.

Nature is full of challenges to our inventive skill and our powers of observation and reasoning. Not an apple falls to the ground in any quiet country orchard that does not challenge us to find out why it falls. The youngest school child will tell you very glibly that it is the force of gravitation. But press him a little further, and ask him what is the force of gravitation, and he will be silent. He cannot answer your question. Neither can his masters. We do not know. These every-day, unexplained facts of nature seem to me like so many giant interrogation points constantly staring us in the face.* Even the clay you tread under foot is, you see, in an humbler though more practical way, another of nature's challenges.

Aluminium has indeed been called "silver from clay," a name referring to its appearance and origin. But you must not be under the impression that because this clay silver costs about as much as the real silver, no efforts have been made to accomplish its easier extraction. I presume that there is not a single chemist the broad land over who has not, at some time—more probably, perhaps, when he was young—given serious thought to the problem. And to-day, I think I may say, without exaggeration, that there are hundreds of earnest workers seeking its practical solution. Nor have their joint results been insignificant. There was a time when the metal in the same cubic yard of clay would have been worth twenty-two, or forty-four, or even sixty-six thousand dollars. There was a time before that when it could have been obtained for no price, however fabulous; and a still earlier time when the very existence of a metal such as this was unsuspected.

To present the outlines of this progressive history, and to familiarize you in some slight degree with the appearance and properties of a metal in whose rising fortune I have so great a confidence, are the full measure of the evening's ambition. So far as I am aware, there is absolutely nothing original in what I shall have to say. My "interest" in the metallurgy of aluminium is the same in kind as your own. It has no market value.

The great French chemist Lavoisier seems to have been the first to suggest the existence of metallic bases in the soils and alkaline earths. Sir Humphry Davy, of safety-lamp fame, attempted to verify the truth of the suggestion, but though he succeeded in isolating the alkaline metals, sodium and potassium, by means of electricity, he failed to separate aluminium.

Oersted, in 1824, came very near to the solution of the problem. Indeed, it is an open question whether he did not isolate the metal, but as his method did not give satisfactory results in the hands of other experimenters, the fame of the discovery of aluminium is generally accorded to Wohler, who, in 1827, decomposed the chloride of aluminium by means of metallic potassium. Here the matter was permitted to rest until 1845, when the German chemist resumed his investigations, and by allowing the vapor of the chloride to pass over potassium contained in platinum receptacles, obtained globules of the metal of sufficient size to enable him to determine its principal properties. It was, however, less fusible than cast iron, and had the disadvantage of decomposing water at ordinary temperatures—two qualities which gave little promise of the future usefulness of the metal, even should it ever be isolated in sufficient quantities to enter the market. It has since been found that the infusibility of Wohler's metal was due to the platinum with which it was alloyed; and the ease with which it decomposed water, to the probable presence of either potassium or the unchanged chloride of aluminium.

And now we come to the epoch of greatest moment in this metallic history. In 1854, the genius of Henri St. Claire Deville was attracted toward the possibilities offered by the new metal. It came about, as we express it, by accident. Deville was experimenting upon the salts of aluminium, and for purposes of the work in hand attempted to prepare the metal according to Wohler's earlier method. He failed in the original purpose of his experiment, but succeeded in obtaining globules of very pure metallic aluminium, and in determining for the first time its true properties. He was thus led to admire the beauty of a metal with which his name has since been inseparably associated; and to devote his large knowledge to an attempt to make the metal available for human uses. It was Michael Angelo who said, "Genius is infinite patience," and its truth was beautifully illustrated in the case of Deville. He applied himself to his chosen task with uncommon persistence and with uncommon results.

He did his work with such thoroughness that only the cheapening of electric energy has enabled us to increase the store of information which he bequeathed to succeeding metallurgists. His first step was to supplant potassium by the cheaper and less dangerous metal sodium. By improvements in the manufacture of this indispensable reagent, he reduced its cost to a mere tithe of what it had formerly been. In the production of the chloride of aluminium he also introduced better processes, and by carrying out Wohler's reaction, thus modified, on a large scale, Deville placed aluminium on the list of commercial products.

During the latter part of his work, he enjoyed the patronage of the Emperor Napoleon III., who was chiefly actuated, it is said, by the hope that the extreme lightness of the metal would make it valuable in naval warfare. At the Paris exposition of 1855, it was first exhibited in public. A large bar of the metal was shown bearing the title, already quoted: "Silver from Clay." The first article made of aluminium, of which I find any record, was a baby's rattle, for which the material, on account of its extreme sonorousness, was admirably adapted. It was intended for the Prince Imperial, the poor boy who afterward lost his life in Zululand.

France has ever remained the home of the aluminium industry. Of recent years, it has also developed to an encouraging extent in England. It has gained but a limited hold among the activities of Germany, Switzerland, and the United States.

The methods of preparing metallic aluminium in vogue at the present time do not differ essentially from those of the past. If they have any distinctive feature, it lies in the completeness and perfection with which the various details have been worked out. It is in this humble though all-conquering way that the successes of to-day have been achieved. If one were to seek out all the methods, proposed as well as provided, for the isolation of aluminium, the task would be much more difficult than the one I have undertaken. But as our purpose includes only the consideration of those processes by which the market is actually being supplied, I shall sufficiently tax your patience if I ask you to regard the three methods of reduction which now divide the attention of practical metallurgists. These are: 1, Deville's method in its modern form; 2, electric methods, which include both those in which the current is used simply as a source of intense heat and those in which the selective action of electrolysis is utilized; and 3, that indefinite though promising class of methods which may be summed up under the general name of projects.

At the present time nearly all the metallic aluminium produced is made according to Deville's method. It is the sole source of the metal in France and in England, and, indeed, it has recently been so greatly improved that unless some exceedingly advantageous method of reduction is proposed, it promises to remain so. The study of the metallurgy of aluminium is therefore largely covered by the study of this one method. There are three distinct operations involved in the process:

1. The preparation of the double chloride of aluminium and sodium.
2. The preparation of metallic sodium.
3. The production of metallic aluminium by the reaction between the double chloride and the sodium.

The manufacture of the two necessary reagents is the most tedious as well as the most expensive part of the entire process. The effort of inventors has therefore been chiefly directed toward the improvement of these preliminary operations.

At the great French establishment at Salindres, the crude material employed is the mineral beauxite, the hydrated oxide of aluminium and iron. It is finely pulverized and then thoroughly mixed with sodium carbonate. The mixture is strongly calcined in a reverberatory furnace, by which the aluminium is converted into a soluble aluminate of soda, while the iron remains as the insoluble sesqui-oxide. By washing with warm water, the two are easily separated. The aqueous solution of the aluminate is then treated with carbon dioxide gas, which precipitates the aluminium as a hydrated oxide, and regenerates sodium carbonate. A second filtration and washing separates the two. To convert alumina thus prepared into the double chloride of aluminium and sodium, it is mixed with carbon and common salt, chloride of sodium. The mixture is made as homogeneous as possible, and formed into balls as large as a good sized orange. These are thoroughly dried at a temperature of about 150° C., and are then packed into earthenware retorts, where they are calcined at a red heat. Meanwhile chlorine gas is introduced into the bottom of the retorts. The double chloride of aluminium and sodium is thus formed, and, volatilizing, passes over into earthen pots, where it condenses and may be stored away for future use. The simple chloride of aluminium was employed in the early days of the industry, but, as it is deliquescent, that is, absorbs moisture from the atmosphere, it is difficult to preserve, and has been almost if not entirely superseded by the more convenient double chloride. The formula of this salt is $Al_2Cl_6 2NaCl$.

A somewhat different method is in use at the English aluminium works at Birmingham. Alum is there employed as the crude material for the production of the double chloride. It is mixed with coal pitch, and calcined at a low temperature. Water is driven off, and sulphur, potash, and alumina remain. After subjecting the residue to the action of steam and air, at a low red heat, it is placed in a vat of hot water. The potash is thus dissolved out, and the insoluble alumina collected and dried. It is then converted into the double chloride by the usual process.

The second operation in Deville's method is the preparation of metallic sodium. As commonly carried out, the operation presents no great difficulties, but it is wasteful and therefore expensive. I give it in some detail, because I want you to fully appreciate the cleverness of an improved method devised by one of our compatriots, which promises to radically change the conditions of the aluminium industry in Europe. The older process, then, consists in reducing sodium carbonate by means of charcoal. As the carbonate is easily fusible, were the two simply heated together, the result would be that the carbon would float on top of the liquid mass, and, consequently, fail to accomplish its work of reduction. It is, therefore, necessary to add about fifteen per cent. of lime, in order that the mixture shall remain infusible and the carbon and soda be kept in contact with each other. The three reagents are mixed as intimately as possible, and subjected to a preliminary calcination at a red heat. This makes the mass more compact, and removes a considerable amount of carbon dioxide. It is afterward placed in small wrought-iron cylinders and heated to a temperature of perhaps 1,400° C. At this heat the reaction between the soda and charcoal takes place; the alkali is reduced and distills over into suitable condensers. Only about two-fifths of the metal contained in the charge is recovered. The greatest waste, however, is in the labor, the wear and tear of the "plant," and the fuel required to attain so high a heat. All of these causes combined have made sodium an expensive metal. It has been selling in this country for $1.50 a pound, and it has been calculated by a competent English chemist that on the other side of the water it costs four shillings per pound to produce. As it takes something over three pounds of sodium to make one pound of aluminium, it will be seen that this item alone is largely responsible for the high price of the metal. Cheap sodium means comparatively cheap aluminium.

The improved process, to which I have alluded, is that invented by Mr. H. Y. Castner, of New York City. It has not been the result of chance, but of elaborate and systematic experimentation. Mr. Castner, I understand, was attracted to the aluminium problem while he was yet a student at Columbia College. After an examination into the conditions of its metallurgy, and the possible directions for improvements, he came to the conclusion that the most probable field for better things lay in the cheaper production of sodium, and accordingly he devoted himself to that. I think he worked on the problem for a couple of years. The result of his work has been the production of a process so admirable that the only fault I have to find with it is that I did not invent it myself. Others have felt the same toward the process, and from both sides of the Atlantic warm praise has been bestowed upon it and upon its inventor.

The germ of Mr. Castner's improvement is simplicity itself. Instead of making use of an infusible mixture, so that the carbon and sodium compound should be kept in contact, he has obtained the same result by a much more rational device. The little particles of carbon are weighted by means of particles of iron, and so, instead of floating uselessly on the surface of the sodium salt, mix through the whole mass and accomplish their work of reduction under much less wasteful conditions. The improvement you see belongs to the domain of physics, and consists of so simple an expedient as increasing the specific gravity of the reducing agent until it equals or somewhat exceeds that of the fused salt. The process is not in use in America at the present time, but has been warmly welcomed in England. Large works are being erected at Birmingham,

* Although in these days it requires more courage to declare a thing impossible than possible, Prof. Helmholtz has recently expressed the opinion that gravitation is incomprehensible, and Mr. Herbert Spencer has long regarded it as belonging to the unknowable.

where both sodium and aluminium will be final products.

Caustic soda is used in preference to the sodium carbonate. The reaction is represented with sufficient accuracy by the following equation:

$$6NaOH + FeC_2 = 2Na_2CO_3 + 6H + 2Na$$

The carbide of iron here symbolized is replaced in the practical working by a specially prepared mechanical mixture, which is found to act as a perfect equivalent. The so-called "carbide" is prepared by mixing together definite amounts of finely divided iron and melted pitch. When the mixture cools, it is broken in pieces and coked in suitable retorts. This finely ground metallic coke is the reducing agent which has solved the problem of cheap sodium. The reduction is carried out in capacious cast iron crucibles. The charge consists of caustic soda of the highest obtainable strength and the proportion of so-called "carbide" needed to satisfy the formula given.

The charged crucibles are placed in a small furnace, where they are moderately heated for about thirty minutes. The mass fuses, and for a time boils with considerable violence, owing to the plentiful escape of hydrogen. At the end of the preliminary heating, the fusion becomes quiet and the crucibles are transferred to the distilling furnace. Here each crucible is placed upon a small elevator platform and is raised into position. The covers of the crucibles are stationary, and are made with convex edges. The crucibles themselves have grooved edges in which a little powdered lime is placed. By simply raising them into the furnace they are effectually sealed during the process of distillation, and may readily be detached when that process is completed and a freshly charged crucible is wanted. Tubes project from the stationary covers and lead to the condensers where the distilled sodium again solidifies. The hydrogen escapes from a small opening in the opposite end of the condenser, and is generally lighted in order to show how the distillation progresses. The operation lasts about an hour and a half and is carried out at a temperature of about 825° C., instead of 1,400° as in the older method. The residues consist mainly of carbonate of soda and metallic iron, both of which are again utilized in future distillations, the one in the form of caustic soda, the other in the reducing "carbide." The whole process is extremely simple and ingenious. It will produce metallic sodium at a cost of less than one shilling a pound. The English company, which is now putting the process into commercial operation, promises to place aluminium on the market in a few months at a price not greater than $5 a pound. If this can be done successfully, the uses to which the metal is put will be greatly increased, for it is making its way in certain fields at more than double that price.

I have dwelt upon Mr. Castner's invention with particular pleasure, both because it comes from a thinking rather than a so-called "practical" man, and because it is so neat a solution of a difficulty of somewhat long standing that it should encourage others to attack similar problems in the faith that equally simple solutions are to be found, if one will but look with sufficient persistence.

We have now come to the third operation in Deville's method, the utilization of these expensively won reagents in the final reaction by which metallic aluminium is produced. A difficulty which beset the early metallurgists was the provision of a flux sufficiently light to permit the reduced metal to sink to the bottom of the reducing hearth, and so unite into an available mass. This is now met by the use of cryolite, which serves the purpose to excellent advantage.

The furnace in which the reaction is carried out is a small affair, built after the reverberatory pattern. It is securely bound together by iron tie-rods, for the interior of the furnace during the operation is the scene of pretty severe cannonading. When the double chloride of aluminium and sodium is brought into contact with metallic sodium in the heat, the sodium, by virtue of its greater affinity for chlorine, displaces the aluminium, setting it free in the desired form of a metal, while the chloride of sodium so formed unites with the cryolite and forms a very light and fusible slag. The reduced metal is run off into moulds and at once cast into marketable ingots. A portion of the slag contains enough aluminium in the form of scattered shots of metal to make its reworking profitable.

In these days when the electric methods are promising so freely and so much, it is common to regard Deville's method as rather a thing of the past, but as it has produced, and is still producing, the bulk of all the aluminium in the market, I think it not unwise to go on the principle that "a bird in the hand is worth two in the bush," and familarize one's self with what is actually being accomplished before devoting one's attention to those achievements that are expressible only in the future tense. This is my excuse for having considered at such length an "old-fashioned" but constantly improving method.

In the employment of electricity in the reduction of aluminium there is, at the present time, an atmosphere of hope rather than of realization. Of its ultimate success one can hardly doubt, who has watched its course in other fields. It presents to us a power that furnishes at once an intense heat, or an ability to control chemical action, that is almost irresistible. The Cowles process depends upon the first of these functions, while all electrolytic methods, as their name implies, depend upon the latter.

It is quite within limits, I think, to say that the Cowles process is the most important among all the electric methods. It does not, at the present time, produce pure aluminium, but simply alloys of the metal with copper. These, however, are of such high value that they deserve all of the attention that they are now receiving. The ore used in this process is preferably the corundum obtained from the Southern States. The furnace in which the reduction is carried out is, in its simplest form, a rectangular box of fire clay, lined with powdered charcoal. The electric terminals are huge arc-light carbons projecting from each end of the furnace. The space between the ends of the terminals is filled with a mixture of ore, granulated copper, and coarsely pulverized carbon. When the current passes, the resistance offered by the carbon causes so intense a heat that the oxide of aluminium is reduced, and the metal formed unites with the now molten copper. It will be observed that the passage of the current is continuous, and that its only function is to produce a heat far more intense than that obtainable by ordinary processes of combustion. The result of this electric smelting is an alloy containing anywhere from a few per cent. of aluminium up to forty or more. It is cast into ingots, analyzed, and remelted with sufficient copper to form an aluminium bronze of the desired proportions. The electric furnace has been of late much improved, and many refinements introduced into the process. These have made it a commercial as well as a scientific success. As power is the great desideratum, the Cowles company has located its new works at Lockport, N. Y., where it has available water pressure to the amount of 1,200 horse power. To those who are sensible of the wonderful beauty of the correlation of forces, there is something highly instructive in this quiet transformation of the power stored in a waterfall into mechanical motion, into electricity, into heat, until it finally loses itself in the work of chemical dissociation. I understand that at the present time it costs, by this method, something less than forty cents per pound to produce the metallic aluminium in the alloys now on the market. They are sold, the company informs me, at the rate of three dollars per pound, with the copper at the market-rates. As one of the chief uses of the metal is in the aluminium bronze thus produced, the Messrs. Cowles have solved a very important problem in the metallurgy of aluminium. The process having been so successful in the production of alloys of the metal, it has not unnaturally aroused the hope that it might become a source of the pure metal itself. The function of the copper is to collect and preserve the aluminium as it is reduced. Were it absent, difficulties would arise in the collection of the metal and also from the fact that it would unite with the carbon to form a yellow, crystalline carbide of aluminium, which would require subsequent treatment. It is believed that the copper and aluminium form a true chemical compound, for their union is attended with the disengagement of heat. It is improbable, therefore, that they can be readily separated by any liquation process. There are other metals, however, with which this would be possible. Tin is one of these. When this metal takes the place of copper in the electric smelting, an alloy of tin and aluminium is produced, which, on being subsequently melted with the proper proportions of lead, yields a metallic bath consisting of an alloy of tin and lead beneath and a layer of pure aluminium above. The perfecting of this process promises an abundance of the pure metal at a very low price. It is not yet carried out on the commercial scale, but I understand is at present the subject of very careful and persistent study. That it may meet with the most ample success is the wish of all chemical spectators—except those who have rival processes in mind.

Still another modification of the Cowles process has been brought into vogue by the requirements of the Mitis castings in wrought iron. It consists in the substitution of iron for copper, and the consequent production of alloys of aluminium and iron. Only a few years ago the expression "wrought iron castings" would have been received with incredulity if not ridicule. The high temperature at which wrought iron melts and the difficulty of keeping it sufficiently fluid to cast with any success have limited the working of the material almost entirely to forge processes. Mr. Peter Ostberg, a Swedish engineer, has, however, so far conquered these conditions that the Mitis castings are now to be found in the regular metal market. He has won this victory by means of aluminium. An alloy always melts at a much lower temperature than the average fusing point of its constituent metals. Wrought iron melts approximately at 4,000° F., but if even a fraction of one per cent. of aluminium be added, the needed temperature is reduced by at least 500°. It is on this principle that the Mitis castings are made. To fluid wrought iron a small amount of metallic aluminium is added, whereby the fusing point is reduced to about 3,500° F. But the temperature of the resultant alloy is little below 4,000°. The thermal difference, or degree of superheating, permits, therefore, a leisurely and accurate casting before the metal approaches its point of solidification. The presence of the aluminium is stated to have no disadvantageous effect upon the metal, but rather to increase its tenacity. Although such small quantities are used, the present costliness of aluminium would be a serious disadvantage to the process, but as an alloy of iron and aluminium serves the purpose equally well, the Cowles product is utilized and the two processes become mutually helpful.

In the electrolytic methods Germany and Switzerland have particularly exercised their ingenuity, although there have not been wanting inventors in the United States who have worked in the same direction. There are any number of methods, distinctive at least in their name, if in nothing else. Sir Humphry Davy, in the early part of the century, attempted to isolate aluminium by means of electricity, and failed. Both Deville in France and Bunsen in Germany, as early as 1854, electrolyzed the fused double chloride of aluminium and sodium. Since their time the cheapening of the electric current has made the method more practicable. At the present time, however, I know of no aluminium made in this way. The experiments of Dr. Kleiner, of Zurich, have attracted favorable comment, and may give rise to an industrial operation. He subjects a bath of fused cryolite to electrolytic action. In Germany the process of Richard Gratzel appears to be the most promising. I have seen beautiful specimens of the metal made by that process, but I am informed by the New York agent of the company operating it that at present all work is experimental. They hope soon to put their product on the market and will also supply magnesium in commercial quantities.

All of these methods differ from each other, if they differ at all, in the special form of apparatus used, which is supposed to effect a more economical utilization of the current. In principle they are the same, depending simply upon the dissociating action of electricity upon fused compounds of aluminium. The metal collects on the negative electrode. The electrolysis of aqueous solutions of aluminium salts is readily accomplished, but is far too expensive a source of the metal to be industrially available.

Of those various schemes which I have summed up under the name of projects, it is more difficult to speak, for their name is legion. The high prize which awaits the successful inventor of a cheap process for the reduction of aluminium has attracted a class of metallurgical adventurers. They have tried nearly everything that is possible and have proposed nearly everything that is impossible. The regret which I would otherwise feel in my inability to present all of these schemes to your attention is therefore tempered by the consideration that such completeness would not be desirable. It is quite possible that with time some of these propositions will mature into industrial operations. In the absence of any prophetic indications to that effect, however, it will be best to limit our view to one or two processes which have a contemporary interest.

At the present speaking there is but one establishment in the United States where pure aluminium has been a regular commercial product. It is that of Colonel William Frishmuth, at Frankford. It is represented to-night by an admirable display of the metal in the form of ingots, bars, plates, and wires. I am unable to state with any definiteness the manner in which the metal has been obtained, for Col. Frishmuth deems it wiser to withhold this information from the public. His older method consisted in a modification of Deville's, Metallic sodium and a volatile salt of aluminium are generated in separate retorts, and brought together, while still in the state of vapors, in a third retort, where the reduction takes place, and metallic aluminium is precipitated. He tells me that his present method is a combined smelting and electric one, which promises an excellent and inexpensive product. I am not able to speak of it from personal inspection. This small American establishment has an historic interest from being the place where the aluminium cap of the Washington monument was cast.

And now it remains for us to consider specifically the advantageous properties which warrant so expensive and so troublesome a metallurgy. I cannot do better perhaps than to refer you to the metal itself for answer. Like all good things, it is its own best advocate. But like them again, its entire merits only appear on very long acquaintance. It will, therefore, be well to enumerate them somewhat systematically.

Physically, then, aluminium possesses properties which distinguish it from all other members of the metallic family. When pure it has a fine white color, a trifle blue when compared with silver. It is on the whole very pleasing, and well adapted for ornamental usage. Unlike copper or other base metals, it has neither odor nor taste. It is sufficiently malleable and ductile to be beaten out into very thin foil or drawn into exceedingly fine wire. Of the sturdier properties, aluminium has its full share. It is elastic, exceedingly tenacious, and, when hammered, quite as hard as iron. It possesses also a characteristic sonorousness, which leads to the expectation that it may some time become an advantageous constituent of bell metal.

But the physical property upon which our hope for the future usefulness of aluminium chiefly rests is its very small specific gravity. It is but 2·56 times as heavy as water. The significance of this levity will appear more strikingly when comparison is made with some of the more common metals. Thus aluminium is only about a third as heavy as iron, less than one-fourth as heavy as silver, and a little more than an eighth as heavy as gold. You will have a still more feeling realization of this difference on handling these two slabs of metal which Col. Frishmuth has kindly had cast for me. They possess the same volume, but one is of lead and the other is of aluminium, and one is almost five times as heavy as the other. In considering the costliness of aluminium, its levity must be kept in mind. With both metals at a dollar an ounce, a cubic inch of silver would cost over four times as much as a cubic inch of aluminium.

It would be quite safe to leave to your imagination the manifold advantages possessed by a metal at once so light and so strong. Among the smaller articles which one is called upon from time to time to carry about with him, such as watch, compass, opera glass, barometer, surveying instruments and the like, the difference between a light and a heavy material is often the difference between comfort and discomfort. The superiority of an aluminium barometer over one of brass weighing about three times as much will not appeal to you very forcibly on casually handling the two, but carry them on successive days over a rough trail, and your opinions will be more pronounced. In more mathematic surveying work, the weight of transit, level, or theodolite is no small tax upon the user. If the consideration be carried to the more serious problems of portability, the importance of light constructive material looms into still greater prominence. In all our systems of transportation, by land or water or air, the movement of such large masses of dead weight is an economical evil. The wagon is disproportionately heavy, compared to its burden of freight. A train of vestibuled Pullmans is almost as ponderous when empty as when full. The ocean greyhound carries thousands of tons on each transatlantic passage on which no freight is paid. And so one might follow the entire list of portables and observe the immense advantage that would result from the introduction of a metal as light as porcelain and as strong as steel. We might press the question still further, and speculate upon the greater speed at which so light a train might safely be run, since its diminished momentum would permit it the sooner to be brought to rest.

The metal does not, however, need to be in motion to display the merit of a small specific gravity. In our present structures of iron we have almost reached the limits in the way of possible dimensions. Any further increase in size would be followed by a collapse resulting from the mere weight of the material itself. Could this be reduced two-thirds, and the strength remain unimpaired, one can easily foresee the advantage. There is still another direction in which a small specific gravity means something.

This is in the construction of delicate analytical balances. By making the cross beams of aluminium they are almost perfectly rigid and unalterable, and the center of gravity of the system is considerably lowered, with a resulting increase of delicacy. Messrs. Troemner & Co., of this city, now construct their finest balances in this fashion, and also employ aluminium for the smaller weights. It may be of interest to know that two such balances form a part of the equipment of the princely laboratory which Mr. Edison has recently erected on the Orange Mountain.

A word should also be said concerning the behavior of aluminium toward heat. At any ordinary temperature it is absolutely fixed, becoming fluid at 750° C. It

is a good conductor of heat, and consequently of electricity. It has a larger specific heat than any other of the useful metals; that is to say, it requires a longer time to become either heated or cooled. Deville has suggested that by virtue of this property a plate of aluminium would make a good chafing dish.

In its chemical properties, aluminium is not less remarkable. The most useful of these is its complete indifference to the action of either air or water, and its failure to unite with sulphur under ordinary conditions. A metal which will not rust possesses a manifest superiority over iron and copper or any of the so-called base metals. It was this property which determined the selection of aluminium for the apex of the Washington monument. As the metallic oxides are poor conductors of electricity, it is important to have a metal for the tips of lightning rods which will not oxidize, and aluminium would be well adapted for the purpose. As a constructive material, a metal which may be freely exposed to the elements without suffering harm needs no praise. As a simple saver of labor it appeals to our philanthropic feelings. When one recalls the multitude of tired arms that daily struggle with the base affinities of brass and try to ring from it an evanescent glitter, the mere thought of a metal which would dispense with this frictional devotion brings a sensation akin to restfulness.

In resisting the action of sulphur, aluminium possesses a merit much above silver, which, as you know, blackens on the slightest contact with that element. Spoons and dishes of aluminium are particularly suitable, therefore, for eggs and other foods containing sulphur. One more mention, and I will close, without, however, exhausting this catalogue of virtues. In its behavior toward the acids, the metal we are considering shows itself a base of weak affinities. It dissolves very readily in hydrochloric acid, but is almost untouched by nitric and sulphuric. As a substitute for platinum, therefore, in the Grove cell, it has been found to work very well. Toward the weaker acids, such as acetic, it manifests a like indifference, a neutrality which well adapts it for the construction of culinary vessels.

If I have succeeded, by this sketchy statement of the uses of aluminium, in persuading you that the metal is one well adapted to nearly all possible uses, either æsthetic or utilitarian, I have succeeded in making current an opinion which I entertain myself.

I have already spoken, I fear, beyond the proper chronometric limits. Yet I cannot conclude without first anticipating that criticism of incompleteness which, in view of this partial presentation of the subject, would be quite justifiable. I am entirely conscious that I have given but a fragment. Into the heights and depths of aluminium we have scarcely penetrated. In giving this superficial view, however, I have tried to present that side of the cube which most nearly touches the daily affairs of life. By way of caution, I should perhaps add that this view is more favorable than that held by many sober-minded scientists. I do not wish to impose my own enthusiasm upon your better judgment, but, for myself, I have great confidence that before many years shall have passed, some chemist will arise among us who shall succeed in transforming, by his subtiler alchemy, aluminium, the metal of the future, into aluminium, the metal of the present.

NOTE.—The lecturer takes this opportunity of expressing his indebtedness to Messrs. Tiffany & Co., to Mr. Peter Ostberg; to Col. Wm. Frishmuth; to Messrs. Queen & Co.; to Messrs. Troemner & Co., and others, for their kindness in furnishing specimens of aluminium for exhibition.

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The Krupp Works at Essen, who are to manufacture aluminium after the process of Professor Netto, of Dresden, from Greenland cryolite, promise chemically pure aluminium at about $1.55 per pound.

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[Continued from SUPPLEMENT, No. 595, page 9504.]

## RADII OF CURVATURE GEOMETRICALLY DETERMINED.

By Prof. C. W. MACCORD, Sc.D.

### NO VIII.—PATH OF A POINT ON THE PISTON ROD OF AN OSCILLATING ENGINE.

IN Fig. 26, let O be the center about which the crank O C revolves, and I the center of oscillation: the point P upon C I will trace the egg-shaped curve shown, whose greatest length D E will be equal to A B, the throw of the crank. The centers of curvature $x$ and $z$, at the extremities D and E, are readily found as in the preceding case, to which this is analogous. We find the same peculiarity, of an infinite radius of curvature; it is not, however, at the highest point of the curve, but at the position P of the marking point when the line of the piston rod is tangent to the circle described by the crank-pin, and also to the curve itself. Supposing the action to begin at B, it is clear that the instantaneous axis will move upward and to the right in a curve I G, until the position shown in the diagram is reached, when it will be found at an infinite distance upon the line I R perpendicular to I C, the center of curvature being also infinitely remote, upon the line P L parallel to I R. Reappearing upon the opposite side of I R and below O I, the axis will describe another curve H I, while the crank moves from position O C to position O A. Both H I and I G will be tangent at I to the vertical line I $i$, and the evolute of E P D will consist of two branches $z$ M, $x$ N, to which P L is a common asymptote.

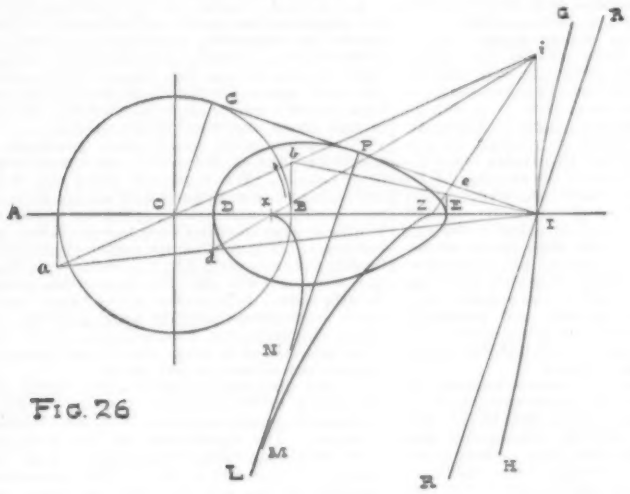



FIG. 26

As in the case of the reciprocating engine, the curve is symmetrical about D E, and the lines above mentioned being therefore symmetrically repeated for the lower half of the curve, the complete skeleton will appear as in Fig. 27, the line R R being a common asymptote to the branches I G, I H.

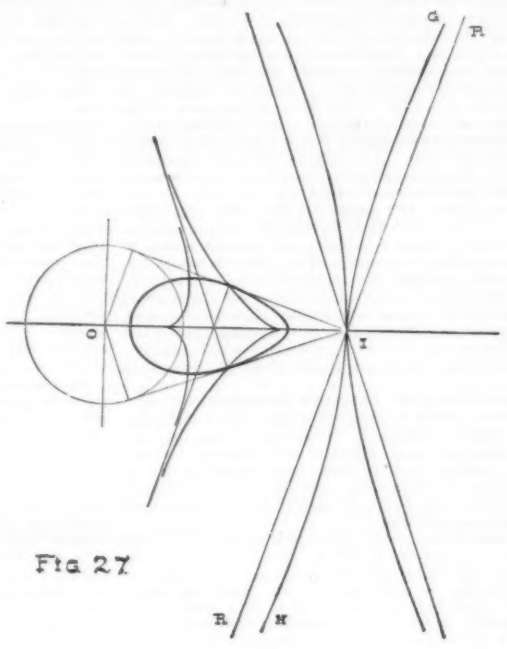



FIG. 27

In Fig. 28 is shown the detail of the process of finding the radius of curvature at any assigned point P of the path. C D is the position of the rod, O C that of the crank; the latter being produced cuts at E the instantaneous axis, a perpendicular to C D at D. Assuming C A as the motion of the crank-pin, the point E will have in consequence a component motion E F perpendicular to O E, determined by producing O A. Draw F G perpendicular to E F, cutting P E, produced in G; O I is turned with an angular velocity represented by the angle E O F, the cylinders will be compelled to move by sliding along D G, with a velocity E G, determined as above explained. But if O I be fixed while D G turns to the right, the cylinders must move along O I, the velocity E I being determined in like manner. Now if both rods be turned simultaneously, the resultant motion will be the diagonal E L of the completed parallelogram, E I and E G being the two components.

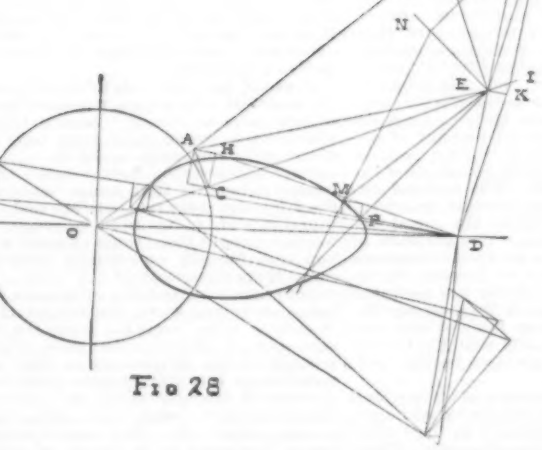
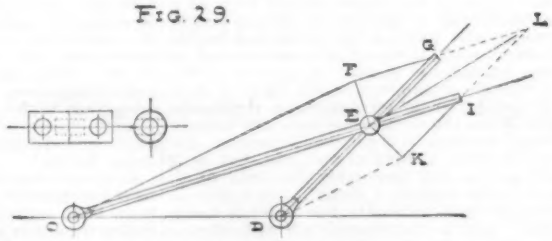



FIG 28

FIG. 29.




It is evident also that, in this latter case, the path of the axis E of the two cylinders could be automatically traced by fixing a pencil in one of them; and by obvious additions, the locus of the instantaneous axis in the preceding diagrams might have been thus described by continuous motion.

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## A NOTE ON HYDROQUINONE DEVELOPMENT.

By J. B. PAYNE.*

FOR some time past considerable attention has been given to hydroquinone as a developing agent, and a large number of formulæ have appeared in the pages of the photographic journals.

In order to thoroughly test the merits of this reagent I requested Mr. Green (operator for our firm) to make a collection of these published formulæ, to test them on various makers' plates, and carefully note the re-

* A communication to the Newcastle-on-Tyne and Northern Counties Photographic Association. Reported in *Br. Jour. of Photo.*

sults. This series of experiments has taken up the spare time at his command for several weeks, and the results have proved extremely interesting and useful. Mr. Green has not been able to carry out these investigations sufficiently to enable him to state definitely the merits and demerits as between pyro and hydroquinone. The latter, however, proved in one direction to have a very marked advantage over pyro, and as this is somewhat important, and has special interest just now when taken in connection with an article which recently appeared in the *British Journal of Photography*, "On the Keeping Qualities of Dry Plates," I took the earliest opportunity of bringing the matter before you.

In the article alluded to, the writer calls attention to the trouble experienced by iridescent stain and fog. It is known to most of us that this surface fog is easily removed by the application of methylated spirit, but none of us cares to have the trouble if he can avoid it. We found that plates which gave the surface fog with pyro and ammonia development showed not the slightest trace of it when developed with hydroquinone. I here exhibit a half-plate negative which was first exposed, then cut into two, one half being developed with pyro. This portion shows the iridescent stain. The other portion was developed with hydroquinone, and is, as you see, quite free from dust.

Hydroquinone appears also to have an equally marked advantage over pyro when used on plates which give a nasty copper-colored fog in the film, as you will see from the negatives before you.

In the various formulæ for development with hydroquinone which have appeared in the photographic journals, there has existed one serious objection to its adoption by the busy photographer, viz., the extreme tardiness of development. With the appended formula the average time of development for a properly exposed plate is from two and a half to three minutes. In a correctly exposed "Mawson" plate the high lights begin to appear in about thirty-five to forty seconds, and then the first appearance of the image is rather deceptive, showing, as it lies in the tray, every indication of a harsh, under-exposed negative; but this gradually disappears and development proceeds more rapidly toward completion.

It is a more agreeable developer to work with than pyro and ammonia, can be modified to give any degree of density, or to bring out detail in cases of under-exposure and instantaneous work, and possesses some advantages over the latter, such as freedom from surface fog, green fog in its various forms, and, not the least important, in the substitution of caustic potash for ammonia, we have an alkali of a much less variable nature to deal with.

Meta-bisulphite of potash, the best known preservative of pyrogallic acid, promises to be equally efficacious in preserving hydroquinone. A sample we have had in solution for six weeks shows no sign of deterioration.

1.

| | |
|---|---|
| Hydroquinone | 4 grains. |
| Meta-bisulphite of potash | 4 " |
| Bromide of potash | 1 grain. |
| Distilled water | 1 ounce. |

2.

| | |
|---|---|
| Potassium hydrate (stick) | 10 grains. |
| Distilled water | 1 ounce. |

Equal parts of 1 and 2.

## THE POSITIVE CYANOTYPE PROCESS,

### OR METHOD OF REPRODUCING WITH DARK LINES ON A CLEAR GROUND FAC-SIMILE COPIES OF DRAWINGS, PLANS, AND TRACINGS.

By Col. WATERHOUSE.*

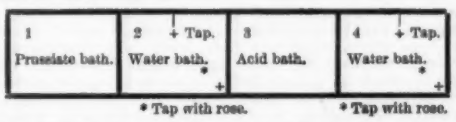
THE following method of reproducing plans, tracings, etc., drawn in black ink on white paper or tracing cloth, is known as the "Positive Cyanotype Process," and has the great advantage of giving copies of the drawing reproduced directly in dark blue lines on a white ground, while, unless a photographic negative be used, the native cyanotype process gives prints with white lines on a dark ground, which are not so easily legible as the positive prints, though the process is simpler. Both methods were the invention of Sir John Herschel, but have been improved and perfected by Poitevin, Marion, Pellet, and others in France, and the positive process is now more commonly known by the names of *Cyanofer* and *Gummoferrique*, which have been given to it in that country.

*Apparatus.*—The apparatus required is simple, and consists of a pressure frame with plate glass, similar to those used for ordinary photographic work, and large enough to take the largest tracing or drawing required. The back board should be jointed in three, and have three crossbars. In large frames four or five crossbars may be necessary. A piece of felt or thick flannel should be cut to the size of the frame and kept with it; in place of the felt a few sheets of clean, soft paper may be used. The glass of the frame should be kept clean on both sides and free from scratches, and the felt or paper pads should be kept thoroughly dry, and be well aired in the sun before use. With printing frames of large size, it may be convenient to mount them on a pivoting stand, so that they can readily be placed at any angle perpendicular to the sun's rays, or turned face downward while being run in and out of the dark room, or during the examination of the test slips. Sometimes, instead of a wooden pressure frame, a thick plate of glass only is used, supported on an India rubber air cushion, the pressure of which against the glass gives very perfect contact. It has also been proposed to obtain close contact in a simple way, without the use of glass plates or frames, by stretching the sensitive paper and tracing over a cylinder; the cylinder has, however, to be kept turned during the progress of the exposure. For work up to the size of a double elephant sheet, the pressure frame will probably be the most convenient arrangement.

*Dishes and Trays.*—At least three trays will be required for chemical solutions and washing; but it is strongly recommended to have four, so that each tray may be kept for a special purpose. Two of the dishes, intended for chemicals, may be made of *papier mache*, or of wood lined with gutta percha or India rubber. As India rubber and gutta percha do not stand the Indian climate well, it will be better to use trays made of wood, well varnished with shellac varnish, or a composition of—

| | |
|---|---|
| Asphaltum | 7 pounds. |
| Beeswax | 2 " |
| Linseed oil | 1 pint. |

Before the varnish is dry, the tray is well lined with strong linen cloth, and then coated again two or three times with the varnish. According to Fisch (*La Photocopie*), trays lined with lead may be used for the prussiate and acid baths. Where the arrangements are fixed, these will perhaps be the most convenient, especially for work of large size. The lead might be varnished with advantage, and the coating renewed as necessary. The other two trays, used for washing the prints, may be made of strong sheet zinc or of wood lined with zinc. For these two trays, water supply, with pressure of at least five or six feet, will be necessary, and should be led into them by India rubber tubes about one inch in diameter, and not quite long enough to reach to the bottom of the trays. The taps may be fixed about 18 inches above the troughs, and the India rubber tube to be from 10 to 15 inches long. A rose may be attached to the end of the rubber tube, but it is better to have an additional rose jet, as noted below. All the trays should be about three or four inches deep, so as to allow room for about one inch depth of fluid without fear of splashing over. The zinc trays should be occasionally scoured with fine sand and a little solution of potash or soda. It will be convenient to have the four trays arranged in order, as shown in the diagram, at a height of 2½ to 3 ft. from the ground:




It will also be found a convenience in washing to place an additional tap at the right hand corner of the washing trays, fitted with a foot or two of half-inch rubber tube, carrying at the other end a copper rose with a bent neck about six or eight inches long, which may be held in the hand, so as to direct the water jet all over the sheet, and thus remove the gummy coating without brushing. It is recommended that a sheet of plate glass should be placed in the zinc tray so as to obtain a perfectly level surface, which will facilitate the brushing, and require less water. It is more easily kept clean than the zinc. For preparing the sensitized paper, a flat board—or, better, a sheet of glass—provided with clips, for holding the paper while being coated with the sensitized solution, will be necessary; also some broad, soft camel or badger hair brushes for coating the paper and clearing the prints. Thomson's patent damping brushes, which consist of a piece of fine felt fastened round a flexible wedge-shaped piece of India rubber attached to a handle, are very suitable for applying the sensitive solution. If these cannot be obtained, a brush may easily be made by fastening some velvet or felt on to the wooden handle of an ordinary four-inch damping brush. Some glass measures, funnels, and suitable vessels for mixing and holding the various solutions will be necessary; also some stoneware jars or wooden tubs in which to prepare the acid and prussiate solutions in quantity, and some stoneware funnels for filtering these solutions when necessary. A Baume's hydrometer for heavy fluids will be useful for ascertaining the strength of the perchloride of iron and prussiate solutions. It should also be graduated with a scale of corresponding specific gravities.

*Chemicals.*—If the sensitive paper is purchased ready prepared, the only chemicals necessary will be ferrocyanide of potassium or yellow prussiate of potash, which should be of good quality, and some sulphuric or hydrochloric acid. Some oxalate of potash will be necessary for removing blue stains from the prints, and caustic potash will be found useful for removing stains from the fingers and for cleaning the zinc trays. For preparing the sensitive paper, the following additional chemicals will be necessary: Gum arabic, which should be of good quality, white and readily soluble; tartaric acid or ammonio-citrate of iron according to the formula employed, and perchloride of iron. The latter salt is commonly sold in amorphous semi-crystalline lumps, but very readily deliquesces into a sirupy fluid, and therefore it may be more convenient to mix its solution to a certain strength by aid of the hydrometer.

A solution of perchloride of iron at 45° Baume contains about 47 per cent. of the anhydrous salt, and its specific gravity at a temperature of 60° F. will be about 1,453.

*Ready Sensitized Paper.*—Paper specially prepared for this process by various Continental firms is now an article of commerce easily obtainable in London or Paris. Some of Pellet's paper obtained some years ago from Mr. G. E. Chapman, of 113 Victoria Street, Westminster, who also supplies all necessary apparatus and materials for the process, has lately been used in the Photographic Office, Calcutta, and found to be in good order. In many cases it might be more convenient to purchase the paper ready for use than to prepare it. Without proper appliances it is difficult to get an even coating.

*Preparation of the Sensitized Paper.*—Two methods have been tried in the Survey of India Photographic Office, Calcutta, both of which have been found to answer well.

*Paper.*—It is important that the paper used for the prints by this process should be hard and well sized, so that the sensitizing solution may be kept as far as possible on its surface, and stains avoided. Good ordinary drawing paper is suitable, also the Rives or Saxe paper generally used for photographic prints. The thick photographic paper No. 50, especially prepared for this purpose by Messrs. Schleicher & Schull, and obtainable from Messrs. Treacher & Co., Bombay, has been found to give the best results. Bank post paper, either thick or thin, is not so suitable.

*The Sensitizing Solution. First Method.*—(*a*) The following two solutions are made up separately:

| | | |
|---|---|---|
| 1. | Gum arabic (best) | 170 parts |
| | Distilled water | 650 " |
| 2. | Tartaric acid | 40 parts |
| | Distilled water | 150 " |

When the gum arabic is perfectly dissolved, which is facilitated by first powdering it, filter the solution (or strain through muslin) into a clean vessel. Then add, constantly stirring, the tartaric acid solution. When they are thoroughly mixed, 100 to 120 parts of a solution of perchloride of iron at 45° Baume (sp. g. 1,453) are added in the same way, very slowly and with constant stirring, after which the mixture should be set aside in a dark place for twenty-four hours. Distilled water is then added until the mixture shows a density of not more than 1,100 on the hydrometer. It is essential that the mixture of the different solutions be made in the order given above. If the perchloride of iron were poured direct into the gum solution, the latter would be immediately coagulated or thrown down in a sticky insoluble mass, which can only be brought back to a liquid state by adding an excess of tartaric acid solution; but when this latter is already present in the gum solution, there is no fear of coagulation. The solution is of an orange yellow. If kept carefully protected from light, it will keep good for a long time.

*Second Method.*—(*b*) Another sensitizing solution, recommended by Captain Pizzighelli, of the Austrian army, which has been found to give brighter prints than (*a*), is made in the following way: Three solutions are made up of—

| | | |
|---|---|---|
| 1. | Gum arabic | 20 parts |
| | Water | 100 " |
| 2. | Ammonio-citrate of iron | 50 parts |
| | Water | 100 " |
| 3. | Perchloride of iron | 50 parts |
| | Water | 100 " |

No. 1 can only be kept a few days; Nos. 2 and 3 keep for several weeks in well-stoppered bottles. When required for use, they are mixed together in the proportions of 20 parts of No. 1, 8 parts of No. 2, and 5 parts of No. 3, *and in the order given*, or the gum will be coagulated. Should this occur after all, the mixture may again be rendered liquid by adding a few drops of glacial acetic acid. In any case, the mixture of Nos. 1 and 2 thickens on the addition of No. 3, and in a short time loses its glutinous properties, and after standing a few hours becomes a thick magma; it is then, according to Pizzighelli, at its best. It has been found, however, difficult to coat the paper with the mixture in this condition, and it is better to add a little acetic acid before adding No. 3, in order to prevent the mixture from thickening. The solution will not keep more than a few days. Whichever of these two sensitizing solutions is employed, the subsequent processes are the same.

*Sensitizing the Paper.*—This operation and all the subsequent ones, except the exposure to sunlight, must be performed in a room illuminated by yellow light passing through one or two thicknesses of yellow paper or calico fastened over the windows, or by candle or weak lamp light. The paper is laid smoothly down on a drawing board or glass plate, and must be firmly fastened down on two sides with pins, rods, or clips. It is of importance to note that the sticky nature of the sensitizing solution is liable to cause a dragging of the paper from its fastenings, which, if not firm, may cause the paper to crease or tear. The sensitizing solution is now poured into a flat dish or plate, and applied to the paper with a soft broad brush, as described above, or with a piece of soft sponge, in an even coat, passing it lightly over the paper, up and down and across, taking care to equalize the coating as much as possible, and to avoid streaks.

The coating should not be too thick nor yet too thin. Each piece of paper coated should be hung up at once to dry in a dark place, preferably in a drying-box heated by a stove. It is important that the paper should dry quickly, so that the solution may not sink into its substance. The paper is said to keep indefinitely, provided it be protected from damp and light. As soon as the papers are dry, it will be well to put them away carefully in an air-tight tin case. It has been found in the photographic office that the paper prepared by the first method will keep in good order, but that prepared by the second method will not keep more than a day or two, and therefore must be freshly prepared as required.

*Printing or Exposure to Light.*—The glass of the pressure frame being thoroughly clean and bright on both sides, close the yellow windows of the dark room, and lay the tracing face downward in the frame, and over it a sheet of the sensitized paper with the prepared or yellow side in contact with the back of the tracing. Over the paper lay a sheet of felt or some sheets of clean paper, which should have been previously dried in the sun, and with both hands carefully smooth outward from the center. Then put in the back board of the frame and fasten down the center bar, having laid the test slips in position, after which fasten down the end bars. Unless the plate glass, the tracing, and the sensitized paper are in close and uniform contact all over, it will be impossible to obtain sharpness in the finished prints.

If a tracing on paper is creased and wavy, it is recommended to fix it on the glass plate by gumming the edges to the glass at intervals. The back of the paper is damped with a sponge, and instantly swells out in waves, but afterward stretches perfectly smooth on drying. In this way the smoothing is done once for all, and perfect sharpness all over the proof is secured. The frame should be exposed toward the south, so that the sunlight may fall perpendicularly upon it, or so that it may get a good direct light. Care should be taken that no shadows or bright reflections fall upon it. The sensitized paper must be kept smooth and free from creases, which would prevent perfect contact with the tracing. In damp weather special precautions must be taken to prevent the sensitive paper being affected by moisture during the operations. The exposure varies according to the intensity of the light. In direct sunlight an exposure of fifteen to forty seconds is sufficient to produce the reduction of the iron salts to the state of ferrous chloride, except in the parts protected by the lines, where it remains in the state of ferric chloride. In the shade or dull light the exposure may be prolonged from one to five minutes, in rain five to fifteen minutes, and in dull, foggy weather may require fifteen to thirty minutes or longer.

One soon learns to guess the proper exposure under ordinary conditions of working. It is important, however, that the exposure should be exactly right, and therefore, unless the exact time required is known

* Compiled in the Photographic Office, Survey of India Department, Calcutta. Reprinted in the *Photo. News.*

from past experience, it is advisable to make use of the following simple test: A few lines of varying thickness are traced on the edges of the drawing to be copied, in the same ink as was used to make the drawing. Over these lines and between the drawing and the sensitized paper are placed some slips of the same sensitive paper, about one inch wide, the ends of which protrude beyond the edges of the printing frame in such a way that each slip can be drawn out of the frame at will. It is then possible, by testing the effects of light on each of these slips, with the developing solution successively at different intervals, to watch the progress of exposure, which is not possible in any other way, because the paper changes color but slightly under the influence of light, and by opening the frame there will be risk of doubling the lines. When it is not convenient to draw the test lines on the tracing itself, they may be drawn on a small separate piece of tracing paper of the same quality as the original tracing, which is placed in a small pressure frame and exposed alongside the tracing being copied, and under exactly the same conditions of lighting. To apply the test, expose the frame to full sunlight for a few seconds, then turn it over to protect the sensitive paper from light, and withdraw one of the test slips. Then immediately plunge the end of the slip which was inside the frame and under the black lines drawn on the edge of the drawing into the solution of ferrocyanide of potassium used for developing, and watch its chemical action for forty to fifty seconds. If the lines appear at once in blue, but the ground of the paper is also tinted blue, the exposure is insufficient and must be continued. These tests are continued, after intervals of a few seconds, with fresh slips of test paper, until a point is reached when the paper remains yellow and quite free from blue spots, but the lines appear sharply reproduced in blue, which indicates that the exposure is exactly sufficient. If, however, the ground of the paper remains yellow, but the lines are broken and faint, the print has been overexposed and should be rejected. The print, having been correctly exposed, is taken to the dark room, and there removed from the frame. If the copies are rolled up, put in a dry place, and excluded from the light, they may be kept for some hours, or even days, before being developed, and thus the printing can be completed under uniform conditions in the best part of the day.

*Development of the Prints.*—This operation must be performed in yellow light. The developing solution consists of a solution of ferrocyanide of potassium at 20 per cent., or about saturation. Should crystals form in the solution, water should be added to just dissolve them. The specific gravity of the solution should be about 1·1275 or about 16° B., and it should not be used to saturation in hot weather, when more of the salt will be dissolved. The solution is conveniently prepared by putting a quantity of the yellow crystals into an enameled pot with two or three times the quantity of boiling water, and stirring the solution from time to time with a wooden rod. The solution is poured off into the tray as required, and more crystals and water added as necessary to keep up the stock. The bath can be used till it is exhausted, and is in no way dangerous.

A sufficient quantity of this solution at the strength indicated above should be poured into the first tray so as to fill it to the depth of about an inch. The print should not be allowed to touch the bottom of the tray, otherwise stains will be caused. Before commencing to develop, the prints are laid, face downward, on a table, and the edges turned up carefully with the aid of a straightedge, so as to form a sort of tray ¾ in. in depth. This renders the sheet more easy of manipulation, and leaves the back white, and in the end saves time. The copy must then be floated, face downward, on the prussiate bath (No. 1), care being taken not to get any of the prussiate solution on the back; any air bubbles must be removed by each of the corners of the copy being quickly lifted in turn by one hand, and gently lowered again, the other hand being used at the same time to drive out the air bubbles from the center. After floating the copy on the prussiate bath for half a minute, the copy must be lifted by raising one end with care. This can be done without getting any of the prussiate on the back, which otherwise would leave blue stains. The copy must now be held up, and the action of the prussiate allowed to continue, but only so long as the yellow ground remains free of blue spots.

The longer the copy can be kept with the film of prussiate on, the stronger and darker will the lines come out. As soon as blue spots begin to appear on the yellow background, the copy must at once be immersed face downward in the zinc tray (No. 2), already filled with clean water. This checks the further action of the prussiate solution. One edge of the paper must now be depressed beneath the surface of the water, and the whole paper then lifted by that edge; the water will thus be made to flow all over the back of the paper. This washing must be repeated two or three times, then the copy must be wholly immersed in the hydrochloric acid bath (No. 3) for five to fifteen minutes, and its surface dabbed all over with a brush in order to start and loosen the blue mucilage. The copy is next taken out of the acid bath, and must be laid face upward in the empty zinc tray (No. 4), where it must be well rubbed all over with a brush to get rid of the superficial blue mucilage, and then copiously flushed with plenty of clean water. The lines of the copy will then be found to stand out blue on a clear white ground. The copy must be hung over a half round piece of wood to dry. If only one zinc water tray is used for washing in after chemical baths, care must be taken to rinse it out well after each washing, as the slightest admixture of the acid and prussiate solutions would stain the copy blue. It saves time if several copies be developed up to the acid bath stage, and left, care being taken to turn each copy face downward before another is put on the top of it; also, always place the copy in the acid bath with the face upward, then brush over with the acid solution, and turn face downward.

*Acid Bath.*—Either sulphuric or hydrochloric acid may be used for clearing the prints. The former requires more precaution in using than the latter. It must be mixed in strong stoneware vessels by adding three parts of the acid to 100 parts of water, and not *vice versa*. The strength of the hydrochloric acid bath is from 8 to 10 parts of acid to 100 of water. A mixture of two quarts of the acid with five gallons of water will fix about 100 copies double elephant size, after which the solution becomes full of blue precipitate, and should be renewed. The objection to the use of this acid is on account of its fuming, but this is slight.

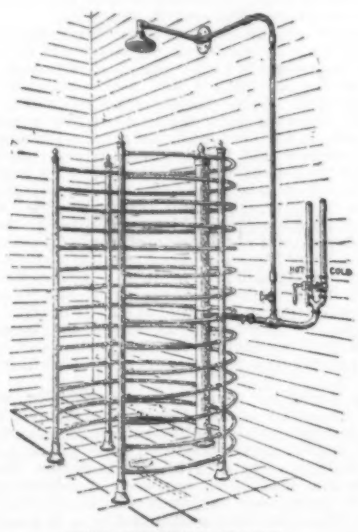
*Causes of Failure.*—1. The ground appears blue. This arises from under-exposure to the light, or from the print having been kept too long exposed to the action of the prussiate bath. 2. The lines are broken and pale, while the ground remains white. This may be due to overexposure, or to the lines of the tracing not being sufficiently opaque to stop the passage of light through them. 3. When the print is put in the acid bath, the lines turn a dark blue, which washes off when being brushed. This arises from insufficient development in the prussiate bath; if the ground is also blue spotted, it is from under-exposure.

*Removal of Stains.*—If, in spite of all precautions, stains or spots of blue appear on the ground of the print, they may be easily removed, or alterations made in the drawing, by means of a solution of oxalate of potash made by dissolving one part of the neutral salt in four parts of water. A solution called "blue solving" is sold ready prepared for this purpose. The liquid is applied lightly with a camel's hair brush to the stains or lines to be erased, and dried off with blotting paper. When dry the parts will appear white. This solution should only be applied to the prints when dry. Blue stains on the fingers may be easily removed by means of a very weak solution of caustic potash or soda, and may be avoided by the use of India rubber gloves or finger stalls. Prints produced by this process are quite permanent and unchangeable by light or damp.

*Preparation of Drawings or Tracings.*—Any drawing or print in black ink on white paper not too thick can be copied by this process; but to secure the best results it is preferable to use tracings with a clear translucent ground and black opaque lines carefully prepared for the purpose. The tracing paper should be quite white or slightly blue, fresh and transparent, of even texture, and free from stains or spots. Old paper, which is generally yellow and brittle, should not be used. The tracing or parchment, papers specially prepared by Messrs. Schleicher & Schull, for photographic work, are to be recommended, and are obtainable from Messrs. Treacher & Co., Bombay. The drawing must be made with perfectly black ink, in firm full lines, especially the finer ones, so that they may be quite opaque. Some Indian yellow or burnt sienna may be added to the Indian ink to give it additional opacity. Care must be taken to keep the back of the tracing clean and free from anything which might print through and interfere with the clearness of the design. As far as possible, all lines usually drawn in color should be drawn in black dotted lines of different kinds. However, if the use of color in the original is compulsory, red lines should be drawn in thick vermilion or burnt sienna; yellow lines with Indian yellow or chrome yellow; brown with burnt umber, sepia, etc.; blue and green lines with a mixture of chrome yellow and dark Prussian blue in different proportions. Pale blue lines for water levels, etc., will not reproduce, and should be drawn in black. All washes of color should be avoided on the tracings. They can be put on after making the reproductions, and may in many cases be replaced by ruling or cross-hatching. Tracing paper is recommended in preference to tracing cloth as more even in texture, and allowing of finer lines being drawn on it.

## THE NEEDLE BATH.

THE shower proper is usually fixed above the "needle" bath, or formed by a continuation of the




THE NEEDLE BATH.

"backbone" of the needle. It is best to have separate regulating valves for the needle and shower; but it is shown with a branch from the pipe conducting to the needle, and with stop cocks. The needle bath is a skeleton-like structure, having a large, hollow backbone and branching ribs. The water ascends the backbone, and, passing into the ribs, squirts out of small holes punctured in their internal circumferences. The bather stands in center of the apparatus, with the ribs encircling him. The ribs should be of ½ in. copper piping, the backbone and lesser supports being of iron, 2½ in. and 1½ in. diameter respectively. In a convenient position for the attendant to work must be placed the regulating valve.

A more elaborate contrivance may be made, which will include needle, shower, ascending shower, spinal douche, and back shower; but this should be left for hydropathic institutions and invalids. Simplicity in these matters should be the great desideratum.

The needle bath is generally left exposed, but it may be inclosed in a metal shield if desired. For this appliance a good head of water is absolutely essential, as with low pressure it is very ineffective. The illustration shows the bath standing on iron shoes. If fixed in a corner, as ordinarily, it can be secured to the wall by such cramps or brackets as necessary.—*Building News.*

## THE GASES OF THE BLOOD.*

By Prof. JOHN GRAY MCKENDRICK, M.D.

I.

MR. PRESIDENT AND GENTLEMEN: The subject I have chosen is a consideration of the gaseous constituents of the blood in relation to some of the problems of respiration. This has been selected both because it deals with a province of physiology in which there are many profound problems connected with the molecular phenomena of life, and also because it gives me the opportunity of illustrating some of the methods of physiological research. I purpose to treat the subject chiefly from the physical standpoint, and to demonstrate some of the phenomena as I would endeavor to do to a class of students, believing that this will be of more interest to many of my audience than if I placed before you anything like an encyclopedic account of recent researches. I cannot help adding that as I speak in the class room of one of the most distinguished physicists of the day, I feel the genius of the place is hovering over me, and I will be impelled to guide you to the borderland of physics and of physiology. It is in this territory that we meet with the most profound questions regarding the nature of vital activity, and it is here that the physiologist and the physicist must join hands in working out their solution.

Respiration may be shortly defined as the function or group of functions by which an interchange occurs between the gases formed in the tissues of a living being and the gases of the medium in which it lives. It is interesting to take a brief survey of the investigations which laid the foundations of our knowledge of this subject, as it illustrates to us the fact taught by the history of all sciences, that those truths which we now regard as elementary were at one time unknown, and have been gained only by laborious inquiry.

The oldest writers do not appear to have had any clear notions even as to the necessity for respiration. Hippocrates dimly recognized that during breathing a *spiritus* was communicated to the body. Many of the older anatomists, following Galen, thought that the "very substance of the air got in by the vessels of the lungs to the left ventricle of the heart, not only to temperate heat, but to provide for the generation of spirits."

This notion of cooling the blood was held by Descartes (1596–1650) and his followers, and seemed to them to be the chief, if not the sole, use of respiration. In addition, they supposed it aided in the production and modulation of the voice, in coughing and in the introduction of odors. The celebrated Van Helmont (1577–1664) strongly expresses these views, and attaches particular importance to the necessity for cooling the blood, which otherwise would become too hot for the body.

About the middle of the seventeenth century clearer notions began to prevail. These rested partly on an anatomical and partly on a physical discovery. Malpighi (1621–94) discovered that the minute bronchial tubes end in air vesicles, or membranous cavities, as he termed them, on the walls of which, in the frog, he saw with his simple microscope the blood flowing through capillaries. The pulmonary plexus was for many years termed the "rete mirabile Malpighii." The physical observations were made by the celebrated Robert Boyle (1647–91), who describes in his treatise entitled "New Experiments, Physico-Mechanical, touching the Spring of the Air," published in 1662, numerous experiments as to the behavior of animals in the exhausted receiver of the air pump.

He showed that the death of the animals "proceeded rather from the want of air than that the air was overclogged by the steam of their bodies." He also showed that fishes also enjoyed the benefits of the air, for, said he, "there is wont to lurk in the water many little parcels of interspersed air, whereof it seems not impossible that fishes may make some use, either by separating it when they strain the matter through their gills, or by some other way."

His conclusion is that "the inspired and expired air may be sometimes very useful by condensing and cooling the blood;" but "I hold that the depuration of the blood in that passage is not only one of the ordinary but one of the principal uses of respiration." Thus, by the use of the air-pump, invented by Otto von Guericke about 1650, Boyle was able to make a contribution of fundamental importance to physiological science.

He also first clearly pointed out the real cause of the influx of air into the lungs. The older anatomists, from Galen downward, held that the lungs dilated actively, and thus sucked in the air; and there was much controversy as to whether the chest, with the contained lungs, resembled a pair of bellows, which was filled because it was dilated, or whether the lungs resembled a bladder, which is dilated because it is filled. Boyle shows clearly that the cavity of the chest is actively dilated, and that the lungs are distended because the "spring" of the air is then less on their outer than on their inner surface.

This simple explanation was not generally accepted, because the minds of Boyle's contemporaries were under the influence of an ancient idea that air existed in the cavity of the chest external to the lungs. This prevented them from seeing the simplicity and accuracy of Boyle's explanation, and to be constantly on the outlook for some mechanism by which the lungs could actively dilate. Such notions were held by Willis, Malpighi, and Erasmus Darwin. The opinion of Darwin is shown by the following passages in the "Zoonomia:"

"By the stimulus of the blood in the right chamber of the heart, the lungs are induced to expand themselves, and the pectoral and intercostal muscles and the diaphragm act at the same time by their associations with them." And, again, "to those increased actions of the air cells are superadded those of the intercostal muscles and diaphragm, by irritative association."

Boyle's observations were published in 1660, and in

* Address to the British Medical Association at its annual meeting at Glasgow. Delivered on August 10 in the Natural Philosophy class-room, University of Glasgow, by John Gray McKendrick, M.D., LL.D., F.R.SS.L. and E., F.R.C.P.E., Professor of the Institutes of Medicine in the University of Glasgow.—*Nature.*

1685 we find Borelli (1608–79), in the second portion of his great work "De Motu Animalium," giving expression to very clear notions regarding respiration. Thus in the eighty-second proposition he shows that the lungs are not the effective causes of respiration, but are passively concerned in the movements; and in the eighty-third proposition he states that the efficient cause of inspiration is the muscular force by which the cavity of the chest is increased, and permits the lungs to be filled by the elastic force of the air. Borelli was also the first, as shown in the eighty-first proposition of his work, to make an estimate of the quantity of air expelled by a single expiration. At the same time he attributed calm expiration to the elastic resiliency of the ribs, and he pointed out that the deepest expiration could not entirely empty the lungs of air (Propositions 92, 93, and 94). While Borelli thus recognized the air as necessary to animal life, he naturally failed in explaining why this was so, being unacquainted with the composition of the air and of the so-called "fuliginous vapors" (carbonic acid, aqueous vapor, etc.), which were supposed to exist in expired air.

I find, in a work by Swammerdam (1637–80), dated 1667, and entitled "Tractatus Physico-Anatomico Medicus de Respiratione usuque Pulmonum," at pp. 20, 21, a description of an experiment in which he immersed in a vessel of water a dog having a long tube inserted in the trachea, and he observed the rise and fall of the level of the water during respiration. This was practically the method followed by Borelli, but I am unable to say which experiment was first performed.

Here I may also refer to the curious experiments of Sanctorius, Professor of Medicine in Padua, who flourished from 1561 to 1636, as being probably the first quantitative estimate of substances escaping from the body. Sanctorius constructed a balance by which he weighed himself repeatedly, and observed what he gained by food and what he lost by excretion. The results appeared in his work "Ars de Statica Medicina," published in 1614, and he states the amount of matter separated by pulmonary exhalation at about half a pound in twenty-four hours. It is not easy to say precisely what these figures represent, and therefore we find the amount, on the authority of Sanctorius, differently stated by writers during the next century. His observations are of interest, however, as being a distinct step in physiological investigation.

Among the contemporaries of Boyle, Pascal, Spinosa, Barrow, Newton, and Leibnitz—all men of the first intellectual rank—was Dr. Robert Hooke, one of the most versatile and able of scientific thinkers. Hooke was born in 1635 and died in 1703. One of the founders of the Royal Society, its early proceedings show that there was scarcely any department of science at the time to which he did not make important contributions. In particular, he showed a remarkable experiment, in October, 1667, to the Royal Society. This experiment, as detailed in Lowthrop's "Abstract of the Philosophical Transactions," vol. iii., p. 67, showed that it was the fresh air, and not any alteration in the capacity of the lungs, which caused the renewal of the heart's beat. It has been said that a similar experiment was performed by Vesalius, but with this difference, that, while Vesalius observed the fact, he failed in giving a rational explanation. He supposed that the movements of the lungs affected the movements of the heart, but he did not see, as Hooke did, that the heart moved because it was supplied with blood containing fresh air. Hooke's experiment is one also of great practical importance as being the basis of the modern practice of using artificial respiration in cases of impending asphyxia.

We thus see that the necessity of a continual supply of fresh air was recognized as being essential to life. It was further surmised that the air imparted something to the blood, and received something in return; but no further advance was made in this direction until the researches of Mayow, a name now famous in the early history of chemistry and of physiology. John Mayow was born in 1645, and died at the early age of thirty-four. His principal work was published in Oxford in 1674. In it, by many ingenious experiments, he showed that combustion diminishes the volume of the air and alters its qualities; that respiration also affects the quality of the air; that an animal will die if kept in a confined space full of air—a fact to be explained, according to Mayow, by saying that the animal had used the respirable portion of the air, and that the residue was unfit for life; and, finally, he showed that an animal suffers if placed in an atmosphere the qualities of which have been injured by combustion. Further, he gave the name of "nitro-aerial spiritus" to the "principle" in the air which, he said, had to do with life, muscular action, and combustion. Thus he no doubt came near the discovery of oxygen, made by Priestley nearly a century later. It would be difficult to estimate the enormous influence on theories of combustion and of respiration exerted by the researches of Boyle, Hooke, and Mayow. They prepared the way in physiological science for the next great step—namely, the identification of the gaseous elements contained in respiration. The dependence of progress in physiology on the state of scientific opinion regarding chemical and physical questions could not be better illustrated than in the history of physiological ideas regarding respiration. Thus the researches of Boyle with the air pump did much to explain the mere mechanism of breathing. Hooke made this even more apparent, and Mayow gave greater precision to the idea that in respiration the blood lost something and gained something. It is difficult to determine precisely, after the lapse of time, the contributions made by each of these distinguished observers, who were contemporaries; but I would venture to say that the germ of the ideas that bore fruit in the mind of Hooke, and more especially of Mayow, may be found in the writings of Robert Boyle.

The researches of Mayow, indicating the existence in the air of a "nitro-aerial spiritus" necessary to life, and the presence in expired air of something deleterious to life, did not immediately produce the fruits one would have expected. At first, his writings attracted considerable attention; they passed through two or three editions, and were translated for Continental readers; but from the beginning of the eighteenth century, nearly twenty years after Mayow's death, they passed almost into oblivion. Thus Hales vaguely refers to him in only two instances, and, as stated by Bostock, "in the discourse delivered by Sir John Pringle before the Royal Society, upon the assignment of Sir Godfrey Copley's medal to Dr. Priestley, which commences with a sketch of the discoveries that had been made in the science of aerology, previous to the period when this philosopher entered upon his experiments, the name of Mayow is not mentioned."

Mayow's writings were first again brought into notice in this country by Reinhold Forster, who gave a summary of Mayow's views in an introduction to his translation of Scheele's essay on "Air and Fire."

As another example of how Mayow's observations were neglected, it may be pointed out that Boerhaave (1668–1738), one of the most learned men of his time, states that he cannot explain the change which the air experiences by respiration; and even Haller, in his great work "Elementa Physiologiæ Corporis Humani," published in 1766, sums up his knowledge regarding expired air by stating that it is combined with a quantity of water and a noxious vapor, and has its elasticity diminished.

The next step in the physiology of respiration was the discovery, in 1754, of carbonic acid, by Joseph Black, then Professor of Medicine and Chemistry in this University. About this time there was much discussion in the medical world as to the use of lime water in cases of stone and gravel. It was supposed that the lime water dissolved calculi, and assisted in expelling them from the body. A discussion arose as to the virtues of lime water produced from different substances. Two professors in the University of Edinburgh—Alston and Whytt—specially investigated the subject, and Whytt asserted that the lime water of oyster shell lime had more power as a solvent than the lime water of common stone lime. This led Black to examine the question. "I therefore," says he, "conceived hopes that, by trying a greater variety of the alkaline earths, some kinds might be found still more different by their qualities from the common kind, and perhaps yielding a lime water still more powerful than that of the oyster-shell lime."

This led Black to his celebrated investigation on magnesia. He showed that in the case of magnesia alba (carbonate of magnesia) the disappearance of the effervescence on treatment with an acid after heating was accompanied by a loss of weight. The substance thus given off he called "fixed air," or what we now term carbonic acid. This led to an examination of the salts of lime, and in 1757 he made two important physiological discoveries, namely: (1) that the fixed air was injurious to animal life; and (2) that fixed air was produced by the action of respiration. These important observations are thus described in his own words: "In the same year, however, in which my first account of these experiments was published—namely, 1757—I had discovered that this particular kind of air attracted by alkaline substances is deadly to all animals that breathe it by the mouth and nostrils together; but that if the nostrils were kept shut, I was led to think that it might be breathed with safety. I found, for example, that when sparrows died in it in ten or twelve seconds, they would live in it for three or four minutes when the nostrils were shut by melted suet. And I convinced myself that the change produced on wholesome air by breathing it consisted chiefly, if not solely, in the conversion of part of it into fixed air. For I found that by blowing through a pipe into lime water, or a solution of caustic alkali, the lime was precipitated, and the alkali was rendered mild. I was partly led to these experiments by some observations of Dr. Hales, in which he says that breathing through diaphragms of cloth dipped in alkaline solutions made the air last longer for the purposes of life."

Fifteen years afterward—namely, in 1772—Joseph Priestley examined the chemical effects produced by the burning of candles and the respiration of animals upon ordinary air, and he made the important discovery that, after air had lost its power of supporting combustion, as by the burning of candles, this property might be restored by the agency of plants. Pushing his experiments still further, he found that air, deteriorated by the breathing of animals, might again become suitable for respiration by the action of plants. In these experiments he employed mice for ascertaining how far an air was impure or unfit for respiration. In 1774, Priestley obtained oxygen by heating red precipitate by means of the sun's rays concentrated by a burning glass. This led to an investigation of the constitution of the atmosphere, and it was shown that it was not a homogeneous elementary body, but consisted of two gases, and that its constitution was remarkably uniform. Priestley showed that by fermentation, combustion, the calcination of metals, and respiration, the air lost a portion of one of its constituents, oxygen.

Thus the chemical researches of Black and Priestley proved that in respiration oxygen was consumed and carbonic acid produced, although the latter fact, owing to the theoretical views of Priestley as to phlogiston, was not fully appreciated by him.

Within a year after Priestley's discovery, a paper on respiration was written by Lavoisier (1743–94) in which he showed that Priestley was correct in stating that the air lost oxygen in breathing, but Lavoisier specially pointed out that it had gained carbonic acid. No doubt Lavoisier was well acquainted with Black's researches, as is shown by the correspondence between these distinguished men. Lavoisier was the first, however, to make a quantitative examination of the changes produced in the air by breathing. In 1780, he performed a remarkable experiment, in which a guinea pig was confined over mercury in a jar containing 248 cubic inches of gas consisting principally of oxygen. In an hour and a quarter the animal breathed with much difficulty, and, being removed from the apparatus, the state of the air was examined. Its bulk was found to be diminished by 8 cubic inches, and of the remaining 240 inches, 40 were absorbed by caustic potash, and consequently consisted of carbonic acid. Still later he performed a more accurate experiment, giving quantitative results. During 1789 and 1790, by a special apparatus, Lavoisier and his friend Seguin attempted to measure the changes in the air produced by the breathing of man. These researches are not of value so much for the results they gave as for the method employed. Lavoisier constructed a still more elaborate apparatus, with which he began experiments. This research, however, he never finished, as, in 1794, he fell a victim to the blind fury of Robespierre. It is narrated that he earnestly requested a respite of a few days to give him time to prepare for publication the results of his investigations. This was denied, and thus perished one of the greatest scientific sons of France.

Stephen Hales (1677–1761) attempted to measure the amount of aqueous vapor given off by the lungs by breathing through a flask filled with wood ashes, which absorbed the moisture, and he estimated the amount at about 20 ounces in twenty-four hours. Similar observations were afterward made by Menzies and by the eminent surgeon Mr. Abernethy. Lavoisier also attacked the problem by an indirect method. Thus he determined the quantity of oxygen consumed and of carbonic acid produced, and assuming that the amount of oxygen was more than sufficient to form the carbonic acid, he came to the conclusion that the excess united with hydrogen in the lungs, and passed off as water. As may be supposed, this method gave widely different results.

Various other attempts were made to estimate the amount of the respiratory changes. In particular, Sir Humphry Davy, in March, 1798, investigated the physiological action of nitrous oxide gas. In this research, published in 1800, he began by observations upon animals; and observations as to the effect of the gas on life, on muscular irritability, on the action of the heart, and on the color of the blood are recorded with great precision. He then passed on to observations on the respiration of hydrogen, and this led him to a repetition of the experiments of Lavoisier and Goodwin. Next he subjected himself and friends to experiment, and recorded a number of interesting physiological and psychical phenomena. This research is of great historical interest as being the first leading to the discovery of a method of producing anæsthesia, or insensibility to pain, by breathing vapors or gases.

Another eminent man who contributed largely to the physiology of respiration was Lazarus Spallanzani, who was born in 1729 and died in 1799. He was educated under the direction of the Jesuits. When about sixteen years of age he went to Bologna, and studied at that university, specially under the tuition of his cousin, Laura Bassa, a woman celebrated in her day for eloquence and scientific knowledge, and who was then a professor in the university. His biographer, Senebier, says: "Under the direction of this enlightened guide he learned to prefer the study of nature to that of her commentators, and to estimate their value by comparing them with the originals they professed to describe. The scholar at once perceived the wisdom of these counsels, and quickly experienced their happy effects. He evinced his gratitude to his instructress in a Latin dissertation published in 1765, which was dedicated to Laura Bassa, and in which he recounted the applauses she received at Modena when, entering the hall where her pupil, on being appointed a professor, was defending a thesis, 'De Lapidibus ab Aqua Resilientibus,' she opposed it with the graces of an amiable woman and the wisdom of a profound philosopher."

Spallanzani became professor of logic, mathematics, and Greek in Reggio in 1754, and about this date he published researches on infusoria. In 1760, he became professor in the University of Modena. In 1765, he showed that many microscopic animalcula were true animals, and in 1768 he published his celebrated researches on the reproduction of portions of the body removed from worms, snails, salamanders, and toads. He paid special attention to the great question of spontaneous generation, showing that infusions of animal and vegetable substances exposed to a high temperature, and hermetically sealed, never produced living things. He also investigated respiration, more particularly in invertebrates. He proved that many such animals breathed by means of the skin as well as by the special breathing organs. He placed many animals, but more especially different species of worms, in atmospheres of hydrogen and nitrogen, and found that, even in these circumstances, carbonic acid was produced. He also showed the production of carbonic acid by the dead bodies of such animals, and reasoned from this that the carbonic acid was produced directly from the dead tissues and not from the action of the oxygen of the air. He contrasts the respiration of cold-blooded and warm-blooded animals, and shows the peculiarities of respiration in hibernating animals. Nor were these by any means superficial observations. They were usually quantitative, and by the use of the eudiometer he analyzed the air before and after respiration. Probably the most important contribution made by Spallanzani to the subject was showing what he states in the following paragraph:

"I inquire not here why the quantity of carbonic acid gas was greater in azotic and hydrogen gas than in common air. I shall only conclude, from these experiments, that it is clearly proved that the carbonic acid gas produced by the living and dead snails in common air resulted not from atmospheric oxygen, since an equal and even a greater quantity of it was obtained in azotic and hydrogen gas; consequently, in the oxygen gas destroyed by the presence of these animals, its base alone is absorbed by them either during life or after death."

But Spallanzani supposed that the carbonic acid thus produced was formed by digestion in the stomach, passed through the tissues, and was then exhaled. Thus he missed a great step in discovery—namely, that the carbonic acid is produced by the tissues themselves. It was, however, pointed out in 1823, by W. F. Edwards, in his work on the "Influence of Physical Agents on Life," that the amount of carbonic acid produced by animal breathing was too great to be accounted for by the amount of oxygen in their lungs at the beginning of the experiment, or by carbonic acid supposed to be in the stomach. The importance of this observation will be seen when we discuss the phenomena of the breathing of the tissues.

(*To be continued.*)

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SPAIN furnishes nearly a third of the world's production of lead. The deposits are extremely numerous, and the ore is of exceptional purity. A specimen of lead ore from the Nuestra Senora del Carmen mine, at Montornes, sent by the proprietress of the mine to the Barcelona Exhibition, is stated to contain 84 per cent. of lead and three and one-fifth ounces of silver to the ton. Some fine samples of lead are shown from the works of the Marquis of Villemeyor, where the daily output is 100 tons, and from the lead works of the Royal Asturian Mining Company. The production of the latter works during the year 1887 included 6,500 tons of pig lead, 16,300 tons of zinc ingots, and 11,000 pounds of fine silver.

# YEAST: ITS MORPHOLOGY AND CULTURE.*

By A. GORDON SALAMON, A.R.S.M., F.I.C., F.C.S.

## LECTURE I.

THE responsibility ordinarily connected with the delivery of a course of scientific lectures is, in this instance, materially increased by the knowledge that I am following in the footsteps of Prof. Graham, to whose Cantor lectures, delivered in this theater, we can, without doubt, trace the first impulse—the first legitimate incentive—to an extended study in this country of the theoretical aspects of the art of fermentation.

Those lectures, however, may fairly be said to have been delivered during a revolutionary period in the history of the science. When Pasteur developed his theories respecting fermentation in explanation of his experiments, he was forthwith involved in a storm of controversy which took years to subside. Indeed, it was not until calm and deliberate judgment had decided the value of his work, that it was deemed sufficiently substantial to constitute the stepping stone to further studies. The majority of these had scarcely been instituted when Prof. Graham first urged the necessity of correlating theory and practice. But they are now complete, or, at any rate, sufficiently advanced to allow of their significance being appreciated. It is, therefore, advisable to pass them in review, with the object of grasping the philosophy of their bearing, of seeing what influence they may be capable of exerting upon the economics of fermentation, and of indicating, if possible, the direction in which subsequent research will tend.

If we desire to make a minute examination of any substance, and to gain an accurate knowledge of its properties and composition, we must investigate it in its simplest and purest form. Applying this axiom to the study of yeast, we have to prepare it in a much less dense condition than that in which it is employed for commercial purposes. We have, as is well known, to dilute it to such an extent that it conveniently admits of critical observation under the lens of a microscope. We then find that the pasty mass, which brewers are accustomed to handle in bulk, is composed of a vast number of more or less globular disks, for the most part wholly disconnected. We distinguish such disks by the name of cells. It is possible, as will be shown hereafter, to separate a single cell from a "crop" of "pitching" or other yeast, and to determine its properties when thus isolated.

If such a cell be introduced under defined conditions into a medium which has been proved by experience to be suitable for the purpose, and if, while still in the medium in question, it be subjected to a continuous microscopic scrutiny, it will be noticed that the cell does not permanently retain the form which it originally possessed. In course of time a prominence or swelling, or it may be more than one, is observable upon the exterior of the cell. At first minute, it gradually increases, until it ultimately assumes dimensions very nearly similar to that of the cell itself. It remains the while attached to the cell, and if examined in this condition will be found closely to correspond with it in all its external characteristics.

The attachment may then gradually be weakened, until at length that which was originally a minute protuberance becomes itself a detached and differentiated cell, similar in appearance to that which gave rise to it. In like manner the newly formed cell may produce one or several others; and by a continuation of the process a sufficient number of cells may be formed to constitute a crop available for pitching purposes. Even more remarkable is it to find that the crop thus produced from the single cell has all the appearances of that used in commerce, and weighs as heavily, whereas the original cell which yielded the crop would not have deflected the beam of the most sensitive balance.

Thus, both by the method of analysis and of synthesis, we are led to the important, yet irrefutable, conclusion that yeast, as it is commercially known, is composed of countless numbers of cells possessing the same appearance, or at any rate so close a resemblance to one another as to make them practically identical, at least within the limits of casual microscopic inspection.

The medium in which this cell formation has taken place has itself undergone modification, and that of a most important character. Some, if not all, of its constituents have become decomposed; if the yeast crop be separated from the medium, it will be found that the latter has undergone a very considerable diminution in weight; heat, the recording index of chemical change, has been manifested; gaseous products have been evolved, and substances originally complex in composition have become resolved into other and more simply constituted bodies. Moreover, it is capable of proof that, but for the presence of the original cell, this series of changes would not have taken place. We are justified, therefore, in attributing them to some influence or influences exerted by the cell and those which may have been formed from it during the progress of the various changes.

I have said that the single cell must, in order to exhibit and induce these phenomena, have been brought into a suitable medium, and under certain prescribed conditions; otherwise the results would have been totally different. If, for instance, the isolated single cell had not been introduced into any medium at all, had been deprived of moisture and of oxygen, it would not have developed protuberances upon its exterior; it would not have multiplied or caused an increase in the original weight of yeast; nor would it have retained its original structural appearance. It would, on the contrary, have become shriveled in appearance and diminished in size, until it would ultimately have become unrecognizable as a yeast cell; and if, after a certain interval of time, a very long interval it is true, it had been introduced into the medium adapted to cell multiplication, it would then have failed to produce a crop of yeast, or indeed a single yeast cell, neither would it have brought about the same decompositions in the medium, nor would it have itself increased in weight.

We see, therefore, that the yeast cell is not always capable of multiplication, and it is obviously of importance to ascertain the limits within which it is possible.

Among the earliest of the conclusions forced upon a student of natural science, and more especially upon one who has grasped the full meaning of the doctrine of evolution, is that which leads him to acknowledge that there are no absolute boundaries, no rigid lines of demarkation, between what are popularly recognized as the animal, vegetable, and mineral kingdoms. True enough, an animal, in the general acceptance of the term, is sufficiently distinct from a vegetable, as widely different indeed as the latter from a mineral; but closer observation shows that, in the world as we know it, there is an overlapping of the three divisions, or a gradual merging of one into the other. There are numerous instances among the lower forms of organized matter in which it requires the skill of an expert to decide as to whether a body is an animal or a vegetable, and in like manner there are certain mineral substances which might easily be mistaken for vegetable matter. Each division has its general attributes, but there are cases in which the differentiation becomes obscured, and identification a matter of great difficulty.

The class of bodies to which yeast belongs falls within this category, and its true position in the realms of nature was consequently for many years involved in doubt and controversy. Indeed, even now there are some—a trifling minority, it is true—who deny the accuracy of the reasoning through which it has been assigned its present position in the accepted classification of aggregated matter. In ordinary circumstances there is but little difficulty in coming to a decision upon such a point. Broad and fundamental differences exist which are sufficiently typical and characteristic to bring the consideration within a comparatively narrow compass. For instance, in applying such tests to the case of yeast, the cell multiplication and its increase in weight at the expense of the medium in which it is placed, coupled with its decay and non-multiplication when placed in unsuitable media, amply prove that it is not a mineral. For such phenomena are clearly those associated with life, growth, reproduction, and death, and as such are absolutely foreign to any of the known properties of minerals.

It remains, therefore, to decide as to whether it is an animal or a plant. In this we are again assisted by reference to the typical conditions pertaining to the life of both. Now microscopic examination of a yeast cell shows that it is surrounded by an envelope or sac of cellulose, and although there may be variations in the thickness of this envelope, there is reason to believe that it is continuous; in other words, that it does not exhibit orifices such as exist in animals for the introduction of food within the system, and for the excretion of products voided as the result of food assimilation; and further, since the single cell is capable of life and reproduction, it follows that the continuous cell wall and the contents which it incloses must constitute the whole machinery which is enabled to manifest these phenomena.

In the case of nearly all animals the food is conveyed into the system by means of an opening adapted to the purpose. Now with the yeast cell such a means of introduction is impossible, because of the existence of the continuous cell wall, which is unprovided with openings; and if the cellulose wall were broken, the life of the cell would be determined. It is therefore clear that the only way in which food can be conveyed into the interior of the cell is by passage through the cellulose. This is, indeed, what actually happens, and it is accomplished by means of diffusion or osmosis. We shall inquire further into the nature of this process at a later stage; for the present it will suffice to state that one of the conditions essential to diffusion through cellulose is that the substance diffused must be in a state of solution; hence it follows that no food can be assimilated by yeast unless it is previously dissolved.

These facts tend to prove that yeast is a plant, because a cellulose wall, and the passage of dissolved nutrient matter through it by osmosis, constitute two of the most essential conditions of plant life. But the conclusion is greatly strengthened, indeed corroborated, by other considerations dependent upon the chemical constitution of the food assimilated. Now animals and plants have this in common: apart from certain mineral elements, which, for the moment, we can ignore, they both require a supply, in some form or other, of the elements carbon, hydrogen, oxygen, and nitrogen. So, as far as information goes, these elements must be aggregated as certain molecular combinations before they can be regarded as nutrifying ingredients.

Among these combinations we recognize a group of complex nitrogenous bodies known as proteins. Their supply would seem to be essential to a normal, healthy, and continued existence both of animals and plants. Suitable animal food contains these protein bodies ready formed in a state available for assimilation, and proportioned in quantity to the climatic conditions and life history of the organisms by which they are consumed. If the animal did not find the protein nourishment ready made, it would not be competent for it to manufacture it or build it up out of the elements of which it is composed. For instance, protein bodies are strictly organic compounds as distinguished from minerals, and it would not be possible for any animal to form protein out of mineral matters. This is not so with plants. They are possessed of the property of forming or manufacturing it from the elements or from true mineral substances, which latter they have the power of breaking down or decomposing in order that the requisite elements may be devoted to the purpose. This is found to hold good with all plants, but with no animals; and it therefore establishes a fundamental difference between the two which is sufficient to constitute a reliable test in case of doubt. Applying it in our own case, we find that yeast is possessed of this power of forming protein out of mineral substances. The point has been abundantly proved by Pasteur. He showed how millions of cells, each containing its requisite amount of protein, could be produced in a healthy and thriving state from a small number of parent cells by introducing the latter into a fluid of the following definite composition: Water, sugar, ammonic tartrate, potassium phosphate, calcium phosphate, magnesium sulphate.

The growth of yeast in this fluid is accompanied by the gradual disappearance of the above-named constituents, and the formation in all the newly developed yeast cells of protean bodies. The latter were obviously not present in the original fluid. It can be proved that the mineral substances present have not the power of forming them in the absence of the yeast or some other similarly constituted organism, and hence it follows that in this case they must have been formed by the yeast, and at the expense of the original constituents of the fluid. Moreover, the recent researches of Hansen have shown that the same results could have been produced by introducing a single cell into the fluid instead of several or many, as was done by Pasteur.

We have it therefore incontestably established that yeast possesses a property common only to plants—in short, that it is a plant; and we know, as a matter of practical experience, that its healthy cultivation is the principal occupation of the brewer, the distiller, and the producer of baker s yeast.

But the successful and scientific cultivation of yeast must involve something more than the mere knowledge that it is a plant. The asparagus of our dinner tables and the weed of our garden path are both plants, yet sprinkling with common salt will secure the growth of the one and the death of the other; and if we investigate the reason for this strange dissimilarity of effect, it is capable of easy explanation when once we have made ourselves acquainted with the life history, the structure, and the composition of the two plants.

I cannot but think that in England there has been a tendency to neglect the study of yeast from this point of view, and if it be so, it is clearly because its practical bearings have not been made sufficiently apparent. I do not underestimate the value of a knowledge of the chemistry involved in the phenomena of fermentation. It is not only essential, it is indispensable, but inasmuch as these phenomena are only among the ultimate phases of the life history of the plant and are subject to modifications dependent upon the conditions of its culture, it follows that it is important to become acquainted with the natural history of yeast in all its bearings. If this be done, the chemistry of fermentation occupies but a subsidiary position, and relieves us from the necessity of being drawn at the commencement of our investigations into the vortex of dispute and doubt by which an interpretation of the nature of fermentative processes has always been surrounded.

Yeast is then a plant. Yet how different from the popular conception of one! How vastly different, for instance, from the oak tree or the cabbage, with which it must evidently have something in common, since all are plants. To determine its position in the vegetable world, to ascertain what sort of plant it really is must obviously constitute our first endeavor, since it is only by thus locating its position that we can arrive at the broad characteristics of its life and development.

We are assisted in this by the masterly work o Sachs, who has made broad and comprehensive classifications of the utmost value. He shows us that a typical plant may be divided into two groups of organs—the root and the shoot. "The root is that part of a plant which becomes fixed on or in a substratum as an organ of attachment, and in the latter case serves for the absorption of nutritive matters contained in the substratum. The shoot or, to express it more generally, the system of shoots of a plant is, on the other hand, originally that part which, becoming developed outside the substratum, produces and increases the substance of the plant, and brings forth in addition the reproductive organs, which never appear on a root." The universal application of this division into root and shoot is well exemplified by the following illustrations of a tree, a seaweed, and a mould fungus.

FIG. 1.—SEEDLING OF THE ALMOND (*Amygdalus communis*), after Sachs.

Sachs proves that in both cases the development will be dependent upon the functions which the root or shoot may be respectively called upon to perform.

It is the necessity of searching for food which induces the development of the more highly organized functions in animals. If, for instance, a man were provided with the means of existence without the necessity of searching for it and striving to obtain it, there would be no occasion for the exercise of his intellectual powers in order to secure a supply of food. Attendant upon the disuse of these powers would be a suppression of brain activity, of the passions involved in food

* Lectures before the Society of Arts, London, 1888. From the *Journal* of the Society.

search, and of the muscular exertions by means of which the dictates of the brain are obeyed. The ultimate result of this would be a condensation of the whole organization of man. The various functions, having no stimulus, no source of irritation moving them to action, would cease to work, and in succeeding generations they would either disappear altogether or, losing their significance and specific differentiation, would become obscured or perhaps unrecognizable. Hence lack of stimulus induces laziness, and this is at once the prime cause of retrogression and the barrier to development.

So it is with plants. The root is an organ of attachment and the conveyor of nutriment, generally moist-

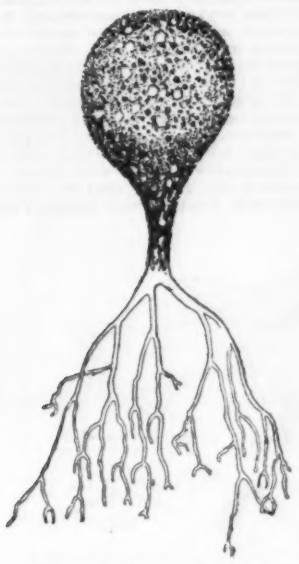


FIG. 2.—BOTRYDIUM GRANULATUM.
(Magnified thirty times. Rostafinski.)

ure and mineral matter, to the shoot. In many plants, and especially in trees, the attachment is a condition necessary to vigorous life, because the shoot system has to develop in a vertical direction, and to grow high above the ground in search of food. The greater the development of the shoot system, both laterally and vertically, the greater must be the strength of the system of attachment, and the more competent must be the means of conveyance of moisture and mineral matter. Hence it follows that the elaboration and development of the root is dependent upon that of the shoot. In other cases the plant may obtain its nourishment nearer to hand and the means of attachment may become useless; the root would then serve only as a means of conveying moisture and mineral matter to the shoot, or the plant might exist in water, and require the roots merely as organs of attachment. There are, indeed, many exaggerated instances of this kind to be found in nature, in which the root is merely indicated, and can scarcely be said to possess any definite function at all.

Is there, then, a suppression of the root and shoot in the case of yeast? If so, why? We have seen that the yeast plant is composed of single cells, each independent and constituting in itself a complete plant. The typical foliage plant, as ordinarily known, is, on the other hand, an aggregation, not of dependent, but of interdependent cells, analogous in many respects to

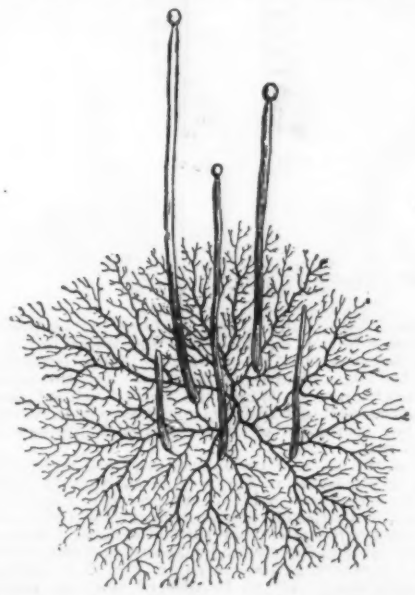


FIG. 3.—PHYCOMYCES NITEUS. (Brafeld.)

the single cell, but differing in the important particular that when separated and alone they are incapable of continuing their existence—of growing and reproducing their kind. These cells, however, are arranged in a defined manner with respect to one another, and are capable of performing specific processes connected with the life of the plant. To this end they secrete, or build up synthetically within themselves, certain ingredients endowed with the necessary chemical and physical attributes. Prominent among these is the substance known as chlorophyl. This body plays a remarkable *rôle* in the nutrition of the plant. It is found to be developed only in certain cells of the plant; it is embedded in protoplasm, and is incapable of exerting its well-known action when separated from these cells. In the presence of light, and under the influence of a certain amount of heat, it is capable of effecting the decomposition of carbonic acid gas. This becomes the chief source of the carbon required in the formation of plant tissue. Out of the carbon products thus decomposed, and in conjunction with water, the cells have the power of building up the compounds subsequently required for assimilation.

Chlorophyl is only found in the shoot system of plants, and in a particular part of it, to wit, the foliage. Hence those plants requiring an abundant supply of carbon compounds for assimilation, and dependent for that supply upon the power of chlorophyl to decompose carbonic acid gas, must be so constituted that they present to the light, and in such a position that the presence of the necessary carbonic acid gas is secured, a large mass of cells containing chlorophyl. In such a case the fully developed root system and the shoot axis have, as Sachs points out, a meaning, for they serve not only to secure the retention of the foliage in the neighborhood of the gas, but also to convey to the cells wherein the assimilable products are manufactured the moisture and mineral matters derived from the substratum. Hence in a plant containing chlorophyl we find the highest and most perfect structural developments, and there can be no doubt that they have all been called forth owing to the activity of chlorophyl in promoting the means of subsistence. Indeed, he further shows that we may go farther and assert that with the inability of plant cells to secrete chlorophyl, and with the acquisition of the power to obtain food under different conditions, there is a corresponding degeneration of structure both in root and shoot, until we ultimately arrive at a stage when the two become practically merged. In such a case we have only the reproductive organs to fall back upon as a means of recognition in their relation to the higher plants, and of these Sachs quaintly remarks that "they succumb less than the vegetative organs to the destructive action of laziness."

It is, then, abundantly evident that the question of food search is quite as important a factor in the determination of the structure of plants as it is in that of animals. Now there are many plants which do not contain chlorophyl, and which are consequently unable to decompose carbonic acid gas in order to obtain their carbon food. We should expect, therefore, that such plants would be devoid of highly developed root and shoot system, and wholly devoid of foliage. They either live as parasites, obtaining their food in a condition suitable for assimilation from their host plant, or they live on organic substances actually undergoing decomposition—*i. e.*, as saprophytes—and absorb their organic constituents before the latter are completely decomposed. Both these conditions of nutrition exist in the great plant division of the fungi, and since it is to this division that yeast belongs, we see at once how it is that we have to deal with a plant in which there is no special development either of shoot or of root. We see also that the intervention of light is not necessary to its nutrition, that it could not assimilate food from an atmosphere of carbonic acid gas, and, since yeast belongs to the saprophytic and not the parasitic class, that the nutrient medium to which I have referred must preferably be one containing organic matter in which a certain amount of decomposition has already been produced. We have therefore already gained certain broad fundamental conceptions respecting the necessary conditions of successful yeast culture.

The next step is obviously to ascertain what are the general characteristics and attributes of the family of fungi to which yeast belongs, and in order the better to do this, let us briefly glance at the position which they occupy with respect to other plants. The classification of plants, which botanists have been almost universally led to adopt with a view to their systematic study, is based upon an examination of their powers of reproduction. It must, however, be borne in mind that the classification is artificial and not a natural one, and therefore mergings of one class into another are by no means uncommon. Subject to this caution, plant life may with advantage be broadly systematized as follows:

An inspection of this table allows us to locate the position of the fungi in the vegetable world. We see that they are flowerless plants; that they do not, like the pea and the bean, reproduce their kind by the sexual organs known as anthers and ovules; that they are cellular plants devoid of leaves; and that they are closely related to the seaweed and the lichens.

Indeed, it is this latter relationship which renders clear the position of fungi in the systematic scheme of natural descent, and leaves but little room for doubt that they, and therefore yeast, are philogenetically connected with the algæ or seaweeds. This statement, which can scarcely yet be said to be irrefutably established, is nevertheless based upon evidence of the strongest kind, and is of paramount importance in all considerations affecting the life history and nutrition of yeast. The lichens constitute an intermediate stage between fungi and algæ, and are indeed compounded of the two, recent researches having clearly shown that they are produced by certain fungi known as ascomycetes, weaving themselves around algæ, usually of microscopic dimensions, and that the resulting product is a lichen. It will be shown that yeast, as at present classified, is also included among the ascomycetous fungi. Hence its relation to other plants bids fair to be capable of rational and accurate explanation.

The absence of chlorophyl in all fungi results, (as might be expected, in a simplification of their structure. Notwithstanding the great diversity of forms which are met with among them, the existence of some as bodies of considerable weight and apparently complex organization, and of others endowed with functions capable of occasioning the most extraordinary and intricate phenomena, it will be found that this simplicity of typical structure is characteristic throughout. Nevertheless, they have most important functions to perform in connection with the economy of life, and but for their presence, or of some class of bodies similarly endowed, the comparatively rapid combustion of dead plants and animals would not be possible. They break down complicated organic structure, and resolve it into simpler constituents, which are subsequently needed for purposes connected with food assimilation. They do this in virtue of a remarkable property which many of them possess of effecting the decomposition of a far greater amount of substance than they themselves can possibly require as food. This is more especially true of purely saprophytic fungi, which include by far the greater number of known species. Nageli has shown it to be true of yeast, and has proved that the weight of yeast actually produced in a given quantity of wort falls far below the amount theoretically required to account for the amount of wort decomposed. A satisfactory explanation of this observation is still wanting.

The decomposition of organic matter effected by fungi may result in the manifestation of two classes of phenomena, fermentation and putrefaction, the former usually, but not exclusively, resulting from the life and multiplication of the various species of saccharomyces; the latter from those of schizomycetes or bacteria. The true classification of bacteria has been attended with great difficulty, more especially because some have been recognized in which the presence of chlorophyl is clearly evident. Excluding these, they are true fungi in the somewhat restricted sense in which Nageli uses the term; they are thallophytes devoid of chlorophyl; the word thallus connoting the simpler forms of plants in which the more elaborate differentiations are no longer apparent. It suggests a fusion of root and shoot into one general mass so far as this involves the whole body of the plant, exclusive of that portion serving as an organ of reproduction.

Accepting this interpretation of the term, fungi may be regarded as consisting of the thallus and the reproductive organs; the latter formed of a bion, or growth, morphologically independent plus the mother cell which produced it. The organs of reproduction are distinguished as spores, gonidia, asci, etc., according to their structure and mode of development. The thallus is further subdivided into the mycelium and the sporophore—the former, the analogue of the root in the higher plants, never bears the organ of reproduction; the latter, the analogue of the shoot, bears the spores by means of which reproduction is effected. The mycelium may vary morphologically in a manner similar

PLANTS.

A.—PHANEROGAMIA (flowering plants containing anthers and ovules).

*Two Subdivisions.*

1. Gymnospermia (ovules not inclosed in ovary).
   - Cycadeæ (are all tropical trees).
   - Coniferæ (juniper, larch, yew, pine).
2. Angiosperma (ovules inclosed in ovary).
   - Monocotyledones (maize, oats, wheat, bamboo, tulip).
   - Dicotyledones (birch, euphorbia, foxglove, tobacco, primula, pea).

B.—CRYPTOGAMIA (flowerless plants not containing anthers or ovules).

*Four Subdivisions.*

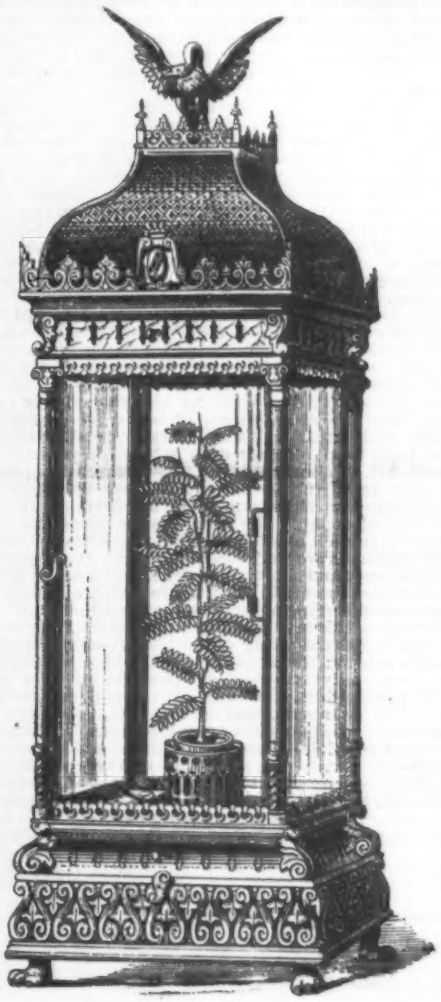
1. Thallophytes (no leaves, no vascular tissue, cells only).
   - (*a*) Algæ (contain chlorophyl).
   - (*b*) Lichens (intermediate between *a* & *c*).
   - (*c*) Fungi (contain no chlorophyl). YEAST.*
2. Characeæ (submerged water plants with characteristic and peculiar system of reproduction).
3. Muscineæ (propagation by alternation of generations).
   - Hepaticæ (liverworts).
   - Musci (mosses).
4. Vascular Cryptogams.
   - Isoporous.
     - *Filices* (ferns).
     - *Equisetaceæ* (horsetails).
     - *Ophioglossaceæ* (adder's tongue).
   - Heterosporous.
     - *Rhizocarpæ* (water ferns).
     - *Lycopodiaceæ* (selaginella).

to the root system of higher plants, with the conditions of life and the peculiarities of nutritive adaptation of the fungus in question. Thus, if the fungus is parasitic, it will generally develop mycelial filaments, termed haustoria, which serve to attach the root of the thallus to the host upon which it lives, and to draw nutriment therefrom. In some cases the mycelium may assume the appearance of a thick felt, which may be removed and handled as an apparently homogeneous mass, this form being familiar to all in the case of the moulds. In others there may be developed, upon filamentous branches of the mycelia, chambers for the storing of reserve nutriment. These storehouses, termed sclerotia, may undergo a specific development of their own, become detached from the mycelium, may be in a resting state for a considerable time, and ultimately give rise to sporophores, which bear spores at the expense of the reserve material above mentioned.

But in these and all other cases the mycelium is typified by the simplicity of its structure. It is invariably formed of hyphæ, which may become interwoven or cemented together by pressure, or in some cases by a species of parenchyma, but which are easily separable as independent hyphæ. These hyphæ are slender, thread-like, cylindrical cells, capable of extension by apical growth, and of subdivision by means of transverse septa, which latter are formed during the progress of their development. The walls of the cylinders are formed of cellulose, differing in some respects from the cellulose of chlorophyl plants, and inclose protoplasmic fluid. The sporophore—the branch or branches of the thallus bearing the spores—is similarly formed of hyphæ, characterized by the same comparative simplicity of structure. They may become morphologically complicated, but in few cases is there great difficulty in satisfactorily referring them to the typical form. Familiar examples of compound sporophores are furnished by the well-known stalked umbrella forms of the edible mushrooms. The propagation of fungi is generally effected by the abjunction or complete separation of cells from the sporophores, which may then develop into bions capable of development. A single cell thus abjointed is termed a spore.

Spores are usually formed in one or two ways by what is known as acrogenous abjunction, in which case they are formed at the summits of hyphal branches by transverse septation of the hyphæ; or they are produced by endogenous division. In this case the spores are produced inside mother cells, and are matured therein. They are then released and are capable of development. In many species the organ of reproduction is produced by the asexual formation of a propagative cell, which separates from the parent, and is capable of developing at once into a new bion. Such a cell is termed a gonidium, and the hypha bearing it a gonidiophore.

*(To be continued).*



THE WEATHER PLANT.

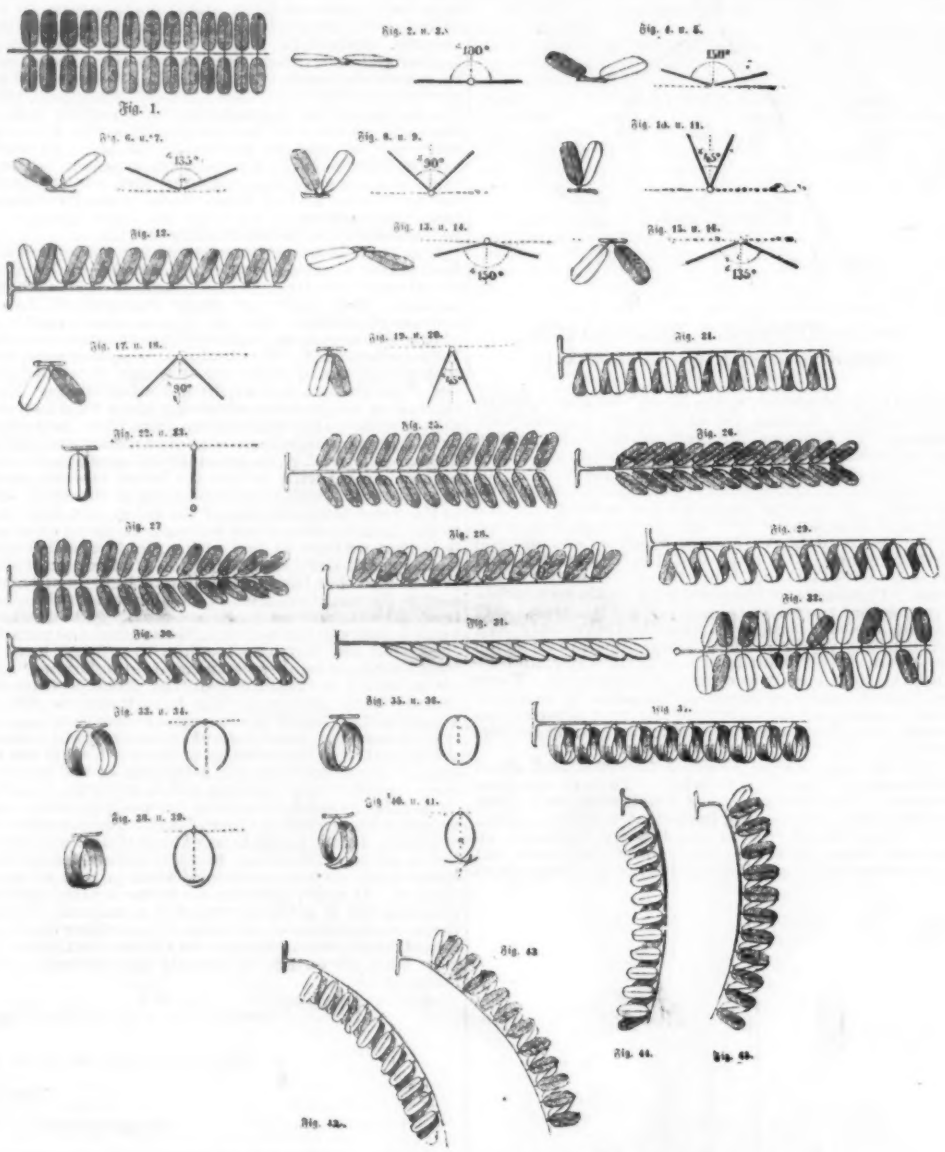
## THE WEATHER PLANT.

IT is a well known fact that quite a large number of plants are more or less sensitive to present or coming atmospheric disturbances, and are, consequently, very characteristically, called sensitive weather plants. It has frequently been observed that the leaves of quite a number of plants alter their positions only when certain changes in the atmosphere take place. A newly discovered and very sensitive plant has been made a subject of special study in relation to weather probabilities by Mr. J. F. Nowack, a chemist in Bohemia, Austria, with a most surprising result.

The plant in question has been observed and tested during the last three years, and has indicated the weather for fully two days in advance with surprising accuracy. Not only rain or fair weather is indicated, but also slight changes, such as clearing, or increasing or decreasing cloudiness. Coming thunder storms, earthquakes, winds, their force, and even, by regular observation, their direction, have been indicated, as well as the rising and falling of the temperature.

This remarkable plant was originally cultivated by Mr. Nowack from seeds obtained from the tropics, and, according to Prof. Weiss, of Prague, its anatomical structure is similar to the sensitive tropic Mimoseæ, and its leaves are provided with movable joints to permit of their bending easily in either direction. Prof. Weiss also finds in the cells on the upper sides of the leaves a substance which, as yet, has not been found in other plants, and which is evidently the actuating force, the rival of "Old Probabilities." This substance is at present under observation, and its nature will undoubtedly soon be further developed, so as to throw more light on the astonishing peculiarities of the plant.

To give our readers a clear idea of the working of the plant as a weather prophet, we refer to the accompanying illustrations, in which the plate represents a glass-covered casing containing a single plant. The leaves on each spray of the plant move up, down, sidewise, or coil up, according to the changes in the atmosphere. In Figs. 1, 2, and 3 is represented the normal position; that is, the leaves standing in a horizontal plane arranged in pairs, each of which has its leaves standing diametrically opposite each other on the stem. When the leaves are in this position the plant indicates a change of weather after forty-eight hours. When the pairs of leaves on each spray rise slightly to an angle of about 150 deg., as shown in Figs. 4 and 5, it is an indication that the temperature tends to clear; and a still further upward movement of the leaves, as shown in Figs. 6 and 7, prophesies increasing clear weather; and when the leaves stand at right angles, as shown in Figs. 8 and 9, fair weather is to come. When a cloudless, clear sky is approaching, the leaves stand at an angle of 45 deg., as illustrated in Figs. 10, 11, and 12, the latter of which represents a full sized spray with ten pairs of leaves.



ILLUSTRATIONS OF THE WEATHER PLANT.

It will be seen that by a constant upward movement of the leaves, a corresponding increase of fine weather is indicated, until the leaves are finally very near together, as shown in the last mentioned figures. This upward movement of the leaves is called positive, while a downward movement of the leaves is called negative. When the leaves move downward from their normal position, as illustrated in Fig. 1, into the position shown in Figs. 13 and 14, an increasing cloudiness of sky is to come. The leaves then stand at an angle of about 150 deg.; and when the leaves move toward each other in their downward movement to an angle of 135 deg., as illustrated in Figs. 15 and 16, then very heavy clouds are sure to appear in about forty-eight hours. When the angle of the two leaves is only 90 deg., as shown in Figs. 17 and 18, the clouds are increasing to such an extent that it will soon rain. Rain is sure to come when the leaves, in their downward movement, stand at an angle of 45 deg., as shown in Figs. 19, 20, and 21. A very heavy rain is indicated when the leaves close up, as shown in Figs. 22 and 23. This also indicates that the rain will continue for some time.

In the above described movements of the leaves the axes of each pair move in a plane vertical to the stem. When the leaves, however, do not move in this direction, but move, in their up and down motion, in a plane inclined to the stem, then the motion of the air is also indicated; that is, the greater the inclination of the plane, the greater the movement of the air for the next forty-eight hours. While Fig. 1 illustrates changeable quiet weather, Fig. 25, in which the pairs of leaves stand at an angle to the stem and in a horizontal plane, illustrates changeable weather with wind. In Fig. 26 the inclination is still greater, and we have an indication of changeable weather with a high wind. In Fig. 27 some of the pairs of leaves stand in the position illustrated in Fig. 1 and some as illustrated in Fig. 25. This indicates that the change of wind commences with the time of observation to last for the coming forty-eight hours. When the outer, inclined leaves will move back into their normal position, it indicates that the movement of the air will soon decrease and finally stop.

When the leaves move upward and are inclined forward, as illustrated in Fig. 28—the corresponding position for very fine weather is illustrated in Fig. 12—the forward inclination indicates a cloudless sky with wind. In a similar manner, when the leaves move downward, as illustrated in Fig. 29, and then are inclined forward in this position, as illustrated in Fig. 30, it indicates rain with wind. It will be noticed that the position shown in Fig. 29 indicates rain. The inclination of the leaves corresponds to the power of the wind to be expected during the next forty-eight hours. Thus, as illustrated in Fig. 31, the pairs of leaves are downwardly and forwardly inclined to a considerable extent, and indicate a storm. A still further inclination of the leaves toward the stem indicates a hurricane.

The electrical disturbances in the atmosphere are also indicated by this remarkable plant about forty-eight hours in advance. When a thunder storm is brewing some distance off, then some of the leaves stand upward and others downward in almost every direction, as illustrated in Fig 32. When the leaves are curved, as illustrated in Figs. 33 and 34, it indicates that a thunder storm is passing over the country about

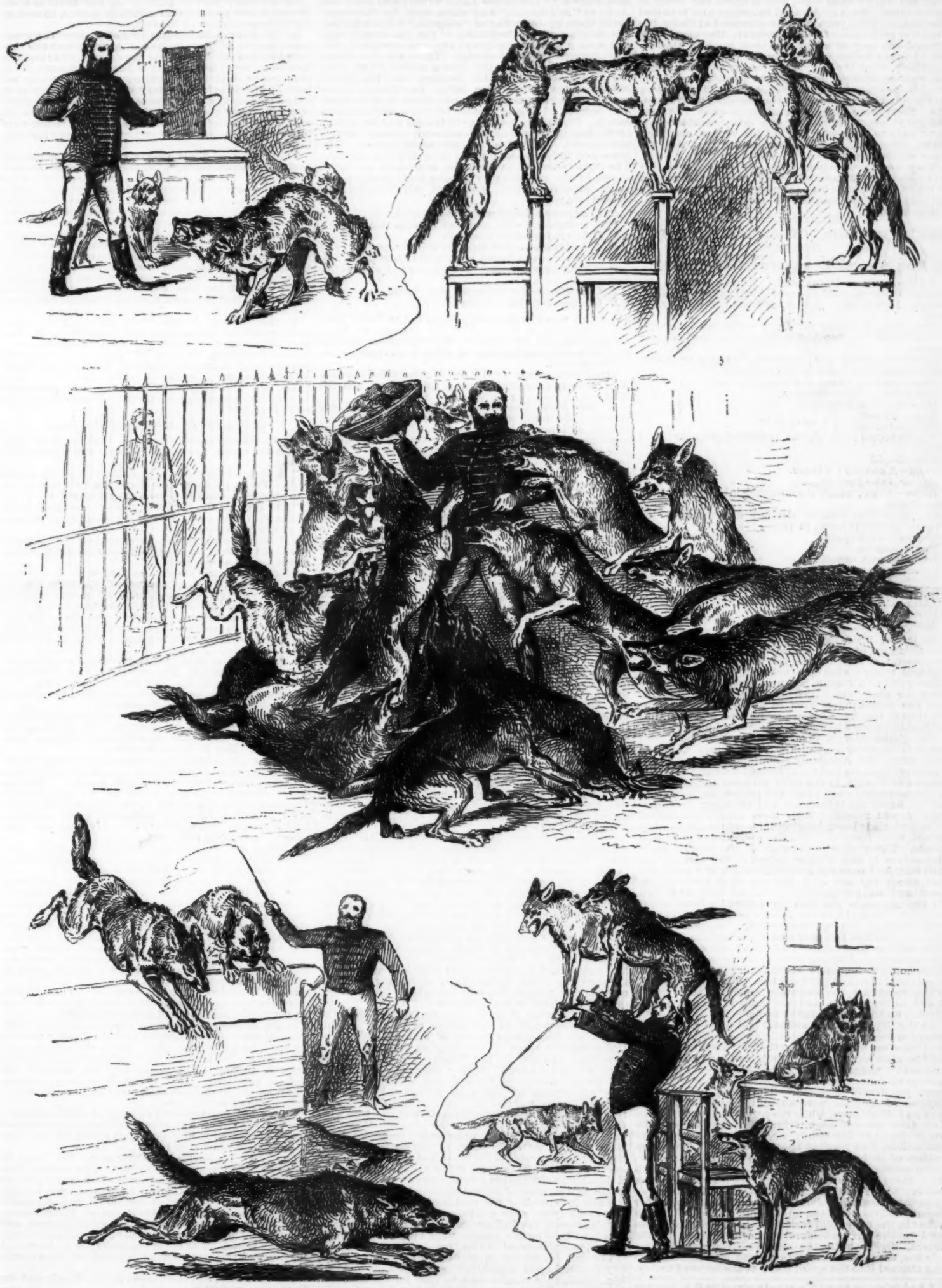
five miles distant from the place of observation. When the leaves appear in the position shown in Figs. 36 and 37 the thunder storm is nearing. If the leaves curl up, as illustrated in Figs. 38 and 39, the thunder storm will undoubtedly pass over the place of observation. If the leaves curve as much as illustrated in Figs. 40 and 41, the thunder storm is local and very heavy. Several of the last mentioned positions of the leaves are observed only on younger sprays.

As above mentioned, distant and near earthquakes are also indicated by this most wonderful plant. When the sprays of the plant assume a downwardly inclined position relative to the trunk of the plant, as illustrated in Figs. 42 and 43, they indicate that an earthquake is going to agitate our globe at a safe distance from the place of observation. When, however, the sprays incline into the position shown in Figs. 47 and 48, the earthquake is going to pass over the place of observation within forty-eight hours.

We have taken the above mentioned statements and illustrations from a book recently published by Mr. Nowack. The plants have been very successfully cultivated by a large firm of seedsmen in Erfurt, Germany. TH. G. H.

## RUSSIAN PERFORMING WOLVES AT THE WINTER CIRCUS.

THE Russian or, more accurately, the Siberian wolves now on exhibition at the Winter Circus are the first ones that have been submitted to man's will and consented to work like vulgar dogs. Up to the present, in fact, the wolf has had the reputation of being abso-



RUSSIAN PERFORMING WOLVES AT THE WINTER CIRCUS.

lutely refractory. Read Buffon and other naturalists and you will find the intelligence and cowardice of the wolf spoken of. Its wildness and love of independence are legendary. And yet the wolves at the circus obey their tamer with docility, and perform all sorts of exercises, such as walking on chairs, ascending stairs, jumping from high bars, and forming living tableaux of the prettiest effect.

The man who accomplished this feat possesses an amount of strength and boldness that is not very common. He is small and stout, and has enormous arms, that are harder than steel, and is quick and lively in his motions. He is a Spaniard by origin, and is named Rodesnido. Five years ago he exercised at Cadiz the lucrative profession of wine merchant. One evening he entered the cage of a lion, and then wagered that he would make wolves work—animals which in Spain, as elsewhere, have the reputation that is so well known. He went to Siberia and brought back, not without trouble, a cargo of twenty-seven, gave up his situation, and devoted himself wholly to the rearing of his charges. His efforts were for a long time in vain. He was obliged to overcome, one by one, many resistances, to fight body to body with each of his whelps, and then make them work together—something that was not done without trouble.

They are now conquered, but not tamed, and this was seen the other evening, when the tamer was able to make a wolf enter his cage only through force. The animals obey their master's will not without protest.—*L'Illustration.*

## ORIGIN OF THE DOMESTICATION OF THE HORSE.*

By RUSH SHIPPEN HUIDEKOPER, M.D., Vet. Alfort.

*Bibliography.* — Pietrement, Milne-Edwards, Sir Charles Lyell, Sanson, Ephrem Houel, Emile Burnouf, Rodier, Pictet, Max Muller, Mariette Bey, Layard, et al.

*Etymology of Terms for Horse.*—The word *horse* is derived from the Sanskrit word *rasa*—a sentiment or passion.

*Rasika*—A horse, *i. e.*, a sensible, ardent, or intelligent animal; used also for the elephant.

*Hros*—Ancient Saxon and Scandinavian.

*Synonyms: Ross*—German.
*Ors*—Dutch and Swedish.
*Rosse*—French. } A sorry jade
*Rozza*—Italian. }

The technical term, *Equus*, is derived from the Zend root.

*Acu*—Rapid.
*Acpa*—A courser; a horse.
*Asp* or *Ash*—Persian.
*Ikkos*—Ælian, which degenerated into *ippos* in the later Greek.

Our adjective, *cavalry*, derived directly from the French, *cheval*, is found in the—
Sanskrit—Tchapala.
Kavi—Kapala.
Irish—Capall, capuill.
Cornish—Kevil.
Welsh—Ceffyl.
Slave—Kobyla.
Latin—Caballus.
Persian—Kawal.
Arab—Chabal.

In taking up a rapid sketch of the origin of the domestication of the horse, and the manner in which this useful, or rather absolutely indispensable, animal was first thrown with man, subdued by him and made subservient to his needs, we must first review for a moment the place which he holds in the animal kingdom and the geographical area in which he was found at the time of the first appearance of man, at which time both animals were in an absolute state of nature.

The Perissodactyla, or odd-toed animals, had their common ancestor among the earliest mammals, at a time when the Allegheny Mountains and the Black Forest of Germany had the luxuriant flora and beautiful climate of Florida, in the little harmless animal known as the acerotherium. From this progenitor the cousins of the horse, the rhinoceros and the tapir, developed rapidly, and reaching their more simple anatomical form and their lesser intellectual condition at an early period, have remained until the present day mere wild beasts. The remaining branch of the family found themselves in the Eocene period of the tertiary age well scattered over the face of the earth as a small animal, about the size of a fox, but with, however, the head and body characteristics of the horse of to-day. In the Americas the *Eohippus* found a home in the lowlands. He had forty-four teeth, seven molars in each arch, without cement, tusk teeth, a complete set of digits on the fore feet, and four digits with an aborting fifth on the hind ones. The *Orohippus* wandered on the mountains, differing from the other member of the family only in the more rudimentary development of the lateral digits of the hind feet. The paleotherium, which resembled the mountain American variety, was found in both high and low lands in France, Spain, Greece, and in Asia as far as India.

In the Myocene these animals had developed to the size of a sheep. Their fifth digit was aborted, the lateral ones were rudimentary, their radius and cubitus had become united, they still retained forty-four teeth, the seven molars in each arch still separated into two groups of four anterior and three posterior, and these were yet devoid of cement. The *Eohippus* and *Orohippus* of America were succeeded by the *Mesohippus* and *Miohippus*, while the paleotherium of Europe takes the name of anchiterium. In the *Pliocene* the subdivisions of the family were more numerous, and the animal had reached the size of an ass. The seven molars of each arch united into a single line and became covered with cement. In the permanent dentition there were frequently but six instead of seven teeth. The *Protohippus*, *Parahippus*, Hipparion or Hippotherium, and *Pliohippus*, and numerous other localized divisions of the family only differed from each other in the more solid fusion of the cubitus and radius and in the gradual more rudimentary form of the lateral digits, until the animals stood upon a single toe, the lateral metacarpals and metatarsals having aborted into the splint bones of the horse of to day, the lateral digits having become the single ergot behind the fetlock. The six molars with cement became the rule, while the seventh molar, which is the "wolf tooth" of our own horses, was the exception. With this development at the end of the tertiary and the commencement of the quaternary periods, the genus *Equus* abounded all over the world; it survived the glacial periods in Europe and Asia, but disappeared entirely from Africa and the Americas, to reappear in the former with the invasions of the Hyksos, and in the latter with the advent of the Spaniards. The Equides, also known to the earlier Latin writers and until 1693 A. D. as "*solidipedes*," and since then by the name given them by John Ray of "*solipeds*," formed numerous families at the beginning of the quaternary age, but soon afterward the genus Equus was reduced into four distinct tribes or species. These are the *Equus caballus*, or the horse; the *Equus asinus*, or the ass; the *Equus hemionus*, or the hemion; and the *Equus zebrus*, or the zebra. The latter, the African representative, can be subjugated, but never domesticated. The hemion of Asia is capable only of a semi-domestication. It has the endurance of the ass and the agility of the horse, but is always treacherous; except for this last quality, it would be a most useful animal. The horse and the ass alone interest us as domestic animals. The *Equus caballus*, or the horse, at an early period, as shown by the cranial types in early fossil deposits, was again subdivided into species, of which eight now remain, viz.:

*E. C. aryanus*—improperly known as the Arab.
*E. C. mongolicus*—the so-called African Arab.
*E. C. hibernicus*—the Irish cob.
*E. C. britannicus*—the English shire horse.
*E. C. frisius*—the Dutch horse and Clydesdale.
*E. C. germanicus*—the Danish and Luxembourg horse.
*E. C. belgicus*—the Ardenner post horse.
*E. C. sequanus*—the Percheron.

A ninth small variety still existed in the lower Danubian countries at the time of the voyages of Herodotus and Strabo, but owing to the custom of castration and the superior advantages of other races it has entirely disappeared.

The *Equus asinus*, or the ass, is subdivided into the *E. A. orientalis* or *africanus*, or Egyptian ass, and the *E. A. occidentalis*, or European or Spanish ass.

In the fossil deposits of Aurignac, in the Haute Garonne, are found the first traces of the horse in connection with man. Here, with human bones and stone implements of the rudest sort, are found the remains of nine species of carnivora and ten species of herbivora; among them the great bear (*Ursus spalæus*), the great cat (*Felis spalæa*), the hyena, the mammoth, the rhinoceros, the great deer, the reindeer, the aurochs, and the *horse*.

The bones remaining of these animals are only the long ones, all broken in the center and bearing traces of the use of the chipped stone implements used to split them open. No vertebræ except the two nearest the head, and no ribs are found. Heads with crushed cranial bones and inferior maxillary bones exist in numbers. In the deposits of Lourds, Milne-Edwards found the bones of man, chipped stone instruments, the bones of the horse, stag, chamois, aurochs, and those of other animals; phalanges, crushed long bones, heads with broken crania, atlases and axes existed in quantity, but no other bones were found; the bone around the roots of the stags' horns and the cannon bones of all animals bore traces of the blunt instruments used to remove the hides.

The troglodytes hunted these animals for food; they found the carcasses too large to transport to their caves, so removed the legs for meat, the heads for the brains, and, after feasting on the flesh, split open the long bones for the marrow. They may also have employed the brains and marrow for tanning the hides, as is done by the Pallas and by some tribes on the coast of the Arctic to-day. No trace of the dog is to be found in these earlier remains.

In the kjokkenmoddings of Denmark we also find the remains of the horse, and in the later tumuli of the same region these remains are found in greater quantities, and with those of the dog more intimately associated with those of man and the early stone implements of the latter.

In the bronze age we find the traces of the horse much more intimately associated with the remains of man. In the second lacustral period of Switzerland, in the dolmens of Denmark and in the Bohemian homes of the human race, surrounded by castings and hammered implements of bronze, are found the remains of the horse, the dog, and the ox in such numbers and in such predominance over the bones of other animals that we are warranted in believing that man had found an easier existence in domesticating the young and wounded animals of these species, and in having them for food and raiment always at hand, than he had before held, in being obliged to make long journeys through the wilds, to slaughter absolutely wild animals, and to struggle back to his cave or hut with the quarter and hide on his shoulders.

We may assume, then, that the first domestication of animals was made in the bronze age. But at this period we find the evidences of man altered. The Dolicocephalic races of Cro-magnon and of Canstadt have been replaced by the Brachy-cephalic tribes of men, who are gradually moving from the Orient into the fertile valleys of Central and Western Europe. The appearance of the more perfected instruments of domestic use, and the close association of the domestic animals with their human masters, correspond with the earliest migrations of the more intellectual and advanced members of the human family from the East. Intermingled with the traces of the domestication of the indigenous races of the horse and the ox of Europe are to be found the remains of the Aryan horse of Asia. Evidently as civilization moved slowly from the Orient, a sufficient number of animals accompanied it to supply the absolute needs of the prehistoric nomads; but, as the troglodytes were conquered, and as the population increased, the indigenous animals were domesticated, and the native people were taught the art of a primitive agricultural life by their invaders.

The first domestication of our animals was a necessity imposed upon prehistoric man, when his awakening intelligence taught him to care for the aged and the infirm. When these and their increasing families could no longer depend upon the precarious chances of the chase, the nobler race of man found that he must hoard a supply at his dwelling. He found that he must foresee the day of his own decline. The stronger discovered that it was easier to live by the labor of the weaker than to work himself. He became an autocrat—a rudimentary civilian—and counted his standing *per caput*, by the number of heads of less intelligent human beings, horses, and cattle which he could command—a capital which has remained to us until the nineteenth century of the Christian era, although sometimes reckoned to-day in dollars and cents.

Such is the primitive relation of the horse to man. We must now pass over an indefinite period to a more accurate association of the two.

In the Balkan Mountains in Asia, where the great rivers flow to all parts of the old world—about the present location of Punjab, the pass which separates the covetous eyes of Russia and of England through India to-day—the first truly civilized people, of whom we have any fairly evident history, developed. They built cities, employed metals, possessed animals in domestication, learned to express their ideas in cuniform inscriptions, multiplied in numbers, and as a result were forced to seek a larger area and greater supply for their needs.

The Aryans, as these people are called, commenced their migrations, taking with them the animals which had already become a necessity, at a period fixed by Emile Burnouf at a little more than 19,000 years before the Christian era. A few thousand years later they had divided into the great Hindoo race, which had followed the bed of the Ganges, and the Iranians or Aryo-Persians, who traveled to the West. By this time their cuniform literature was well advanced. Their religious writings, the *Rig-veda*, the *Zend Avesta*, and *Vendidad*, based upon common law and justice to communities, like those of all later nations, were made, and in them we find the first written history of the horse. In these we find the word *aeva, acpa*, or *asp* indicating the horse.

In the writings of the times preceding Zoroaster and the fall of Djamschid, 1000 years B. C., we find that the rulers and great men were designated with names combining this root of "*asp*," indicating the possession of horses—for example, Shedasp and Gnenasp, both rulers of Irania.

The few following quotations from the large number which are contained in the religious works will serve for proof:

*Acwameda, or Sacrifice of the Horse.*

"Here are my prayers, . . . that the horse with elongated croup will happily fulfill the hopes of the gods. . . .

"It is by happy ways that thou shalt go to the gods. To carry thee thou hast the two racers, the two antelopes, and the chariot drawn by an ass. . .

"The ass cuts the *thirty-four* ribs of the rapid horse. Leave entire the outer parts, that each member shall be properly prepared.

"If those who see the horse cooked say 'it smells good,' cut them a piece. Grant the demand of whomsoever wishes of this flesh.

"May the horse procure us numbers of cattle, of good horses, children, of great wealth. Thou who art pure and strong, make us strong and pure. May the horse, honored by the holoclast, give us strength."

"O horse, after then the mortals and their chariots, and then cattle, and the happiness of their young girls. All living beings search thy favor. The gods would equal thy force. . . .

"His mane is of gold: his feet as rapid as a thought. *Indra* has descended. The gods have come to celebrate the holoclast of him who first has used the horse.

"These princes have given me fifty horses, and I have paid for this present in hymns.

. . . "A pious king, prudent and generous Tryarna, son of Trioris-na, has made me rich; he has given me two oxen harnessed to a chariot, with ten thousand cows. May he remember thou.

"He has given me twenty cows and two horses drawing a precious load [a proof of the value of the horse and that the ox was the beast of burden]. May the racers covered with gold given me by the generous Trasadasyn, son of Purukutis, may the ten *white horses* of Girixita draw me to the assembly of the sacrifices. I have received from Vidata . . . strong and magnificent horses of a red color.

"Young and magnificent, superb and fertile, burdened by its rich banks, it sees on its sides good horses, rapid chariots, flocks with silken wool."

We have in the above proof that the horse was eaten and that he was used for sacrifices to the gods. From the existence of variable colors we have proof of the already ancient domestication of the animal. From the reference to the 34 ribs we have support in proof of the existence of a Mongolian horse which had two less ribs than other species. We have, lastly, proof that the Vedic-Aryans or Indo-Iranians used the horse at the commencement of the Vedic age, that is, 19,337 years before the Christian era.

In the Vendidad, Chap. V., verse 152: The milk of a mare, fresh and pure, is one of the foods prescribed for a woman who has just had a stillborn child.

In the *Rig-veda*, the laws of *Manon*, anterior to the establishment of the Hindoo castes, impose a penalty for the killing of a horse; they decide the ownership of a foal when the mare is the property of one and the horse of another. The sacrifice of the horse to the gods is regulated. Description is given of horses, mounted, in chariots, as pack animals, in races, and of their being of various colors.

Greece did not possess the horse at the commencement of the Heroic Age, though Homer describes the plains as covered with horses at the time of the siege of Troy (1219 years B. C.)

According to legend, Neptune gave the horse to Athens at the founding of the city. The earliest Phenician navigators, who had reached the shores of the Mediterranean as wandering horsemen, and became sailors to satisfy their greed for travel and conquest, placed horses' heads on the prows of their vessels. Neptune, god of the sea, was also named Hippius, and Minerva, goddess of war, received the name of Hippia (*ippos*, a horse). The horse was plentiful in Assyria at the time of the extension of Nineveh by Ninus (3274 B. C.), according to Diodorus.

The excavations in the valleys of the Tigris and the Euphrates, and the translations of the cuniform inscriptions, confirm the accounts of Diodorus as to the

* Read before the twenty-fifth annual session of the U. S. Veterinary Medical Association at New York, Sept. 18, 1888.—From the *Journal of Comparative Surgery and Medicine.*

utilization of the horse by the Assyrians. The researches of Layard at Nineveh show that the horse was used for agriculture as well as for war.

The earliest Greek warriors derived many of their names from the horse, as Hippocoon, Hippodamus, Hippolochus, Hippotheos, who were at the siege of Troy.

The first horse of Achilles and of Hector are described "Xanthe," or yellow red, indicating that the animal was a sorrel. Red (bay), sorrel, white, and dun horses are noted. In the Iliad, xxiii., we learn that horses were castrated on the 16th day of the month, hogs and the ox on the 8th, mules on the 12th. Xenophon, who served as a youth in the army of Cyrus the younger, wrote at length on equitation and cavalry. He gives rules for castration and for the subjugation of vicious horses and kickers. He gives formula for hardening horses' hoofs, as shoeing was then unknown. He describes the perfect horse as one with an open eye, small ears, wide apart at the base, large chest, rounded ribs, large, short loins, and large-muscled croup. In the army of Xerxes the Magi sacrificed white horses to future success.

Under Cyrus horses were sacrificed to the sun, and bulls to Jupiter. Races were run, mounted and in chariots.

Darius placed an impost on the Cicilians of 360 white horses a year.

He fought with a cavalry which is variously given from 41,000 to 200,000. Under Alexander the Great the troops refused to move, as the "*feet* of the horses were *worn* by continuous marching." Shoeing was unknown in the eight conquered countries of Asia Minor, Syria, Egypt, Mesopotamia, Hyrcania, Bactriania, Sogdiana, Persia, and India.

The horse was only used in Egypt at a relatively late period. It did not exist there during the first historic periods. The Egyptians did not possess horses during their first invasions of Asia under Sesostris (3433–3495 B. C., and 12th dynasty). He was imported into Egypt and naturalized at the time of the invasions by the Hyksos (2898 to 1945 B. C.) Under Rameses the Great, the Egyptians, however, had large bodies of cavalry.

Although Arabia is to the vulgar mind the country of the origin of the horse, we find that this animal was only introduced into the peninsula at a very late date.

Herodotus describes the Arabs and Arabia, the two races of sheep, cattle, asses, and goats, the products of the country, the presents given by the Arabians to the kings of Persia, but he makes no mention of the horse. In his accurate descriptions of other countries, however, he describes in detail those of Babylon, of Cicilia, of Media, Thessaly, and India. He details the horses used in the Olympian games, which were won by mares. He describes the army of Xerxes, but of the Arab contingent mentions only their costumes and arms. He says that the "Lybians fought in chariots of war. . . . The Caspirians, the Paricanians, the Arabs, cavalry, equipped like the infantry, except that the last were mounted on camels, which were equal to the horses in speed. These were the only nations which furnished cavalry. The number of horses was eighty thousand, without the camels and chariots. They were organized by nations, the Arabs the last, as the horses were afraid of the camels."

Strabo, an intimate friend of the governor of Egypt, Aelius Gallus, who undertook a disastrous expedition into Arabia, describes the Arabs as a rich commercial people, describes their possessions, says they are great warriors, and that in their caravans they employ only camels.

Of the north of Arabia, Strabo says they are rich in the products of agriculture and cattle, but are poor in horses, mules, and hogs.

Arrian describes the thousands of horses of the army of Alexander; he gives detailed account of the Arabs and the extent of their country, but does not mention the horse.

The Roman authors do not mention the horse of Arabia before the fourth century. Pliny gives a lengthy description of horses of different countries, but does not include Arabia.

The first note of the horse in Arabia is by Ammian Marcellus, a Roman officer of Greek origin in 353 A. D.

The Chinese possessed the horse at a very early period, and their chronology, which antedates in accuracy that of any other nation, and becomes absolute after the year 2698 B. C., when, under the reign of of Hoang Fi, a tribunal of history was established, includes valuable information regarding five other domestic animals.

These were all introduced into China during the conquest of the Eastern provinces by Fo-hi, the 17th king of the 9th dynasty, 3468 before the Christian era. In the reign of Chin Hong, 3218 B. C., the cultivation of the silkworm was added to the agricultural industries. The Chinese word "*ma*" for the horse is found combined into a title of Se-ma, the Chief of the Horse, in 1115 B. C., but horses were then still few and were used for royal gifts.

The royal household had 1,000 chariots of sixteen horses each. A prince had 100 chariots of sixteen horses, to which number he was limited by law. Every 800 families of the people were obliged to furnish one chariot and sixteen horses, with three armed captains and twenty-two footmen.

The Hebrews offer a curious exception to other nations, who, as we have just seen, employed the horse almost universally in prehistoric times. Among these people the horse only came into use with the reign of the Kings. Throughout all the wanderings of the earlier people, no horses were used by them. Under the rule of the Judges, although the increasing luxury and wealth of the people tempted them to emulate their neighbors in the possession of horses for pageants and for cavalry for their armies, the order of Moses forbidding the use of the animal was still regarded. The great legislator of the world wanted his people to be a just and humble one. He wanted them to live among themselves, honoring their own families, and not annoying their neighbors nor their neighbors' goods. He foresaw that the horse was an article of pomp, of vanity, and of war. Its use tempted the owners to long journeys, the possession of cavalry stimulated the people of the day to conquest. He allowed the use of the ass, but forbade that of the horse. Before the voyage of Joseph into Egypt there is but a single mention of the horse in Genesis, although there is frequent mention of numbers of the other domestic animals in the description of the riches of some of the great personages.

The only passages of Genesis which refer to horses or chariots are in reference to the Egyptians, with whom the Jews had intercourse.

We find various animals used for sacrifice by the Hebrews, but never the horse, which among all other nations was so frequently used for this purpose.

We find throughout all the wars of King David that the Hebrews were thrown into conflicts with and captured large bodies of cavalry and war chariots, but no mention is made of the disposition of them. In King Solomon's time, ten centuries before Christ, the magnificence of parade and pageant could no longer regard the religious warning, and we find the great monarch not only using numbers of horses, but taking advantage of his position as son-in-law to the Pharaoh of Egypt not to pay the export duty levied on horses and becoming a great dealer of his country, an example now emulated by many of the race, as the largest horse dealers of New York and all the great European cities to-day are Hebrews.

Job possessed only cattle, but had evidently seen or heard of the war horse, which he evidently greatly admired as an emblem of strength.*

*America.*

We have seen that at the end of the tertiary age the Americas were rich in the equides, but they suddenly disappeared at about the time of the glaciers. The only domestic animal found was the dog. The horse reappeared in this country in 1516, in the island of Bastimentos, and a year later in Mexico. Under Cortez about fifteen horses were landed, of which we have the minute description as to color and qualities. We find the descendants of escaped horses which people the West and South America, in a state of freedom, with the same characteristics of cranium and croup as is found in the *E. C. mongolicus* and its variety, the Spanish Barb.

* References in the Bible to the use of the horse among the Jews: Genesis, xii., 15, 16; xxiii., 2-5; xxxi., 17, 18; xxxii., 5-13-15; xii., 42, 43; xiv., 19-21, 27; xivi., 29-32-34; xlvii., 16, 17; 1, 7, 9. Exodus, xii., 37, 38; ix., 3, 4; xiv., 6-9, 17, 18, 23, 25, 26, 28-31; xv., 1. Moses' command to future king: Deuteronomy, xvii., 15, 16. Punishment of animals, Exodus, xxi., 28-36; theft of animals, Exodus, xxii., 1-5; wandering of animals, Exodus, xxxiii., 4, 5; wandering of animals, Deuteronomy, xxii., 1-4; stolen and borrowed animals, Exodus, xxiii., 9-16; dislike of dogs, Exodus, xxiii., 30, 31; numbers of animals possessed, Numbers, xxxi., 33-35, 42-45; hamstringing enemy's horses, Joshua, xi., 4-6; ignorance of shoeing, Judges, vi., 21, 24.

## A NEW METHOD OF CHEMICAL ANALYSIS IN WHICH CAPILLARY ATTRACTION PLAYS AN IMPORTANT PART.

By CHARLES W. PHILLIPS, Cincinnati, Ohio.

INVENTED in 1872, but not made known on account of the many difficulties arising in connection therewith.

The first difficulty was to obtain pure chemicals. I do not say that I have them even now, so that in my work there are probably some errors that will have to be corrected at some future time, but the many beautiful, characteristic, and delicate reactions have induced me to make the matter public at this time with the hope that some one with better facilities at command may supply what I have omitted and verify what I have done.

The second difficulty was to obtain pure paper. For many years I hunted for a paper that would give even ordinary satisfaction, but could not find it. Recently I received a sample of incomparable filtering paper, which I found admirably adapted to the purpose, and have used it in these experiments.

These difficulties having now been largely overcome, I shall proceed to describe the reactions of all the important metals of the six groups with four reagents, making in all 116 reactions, leaving many curious and beautiful reactions, with special reagents, for some future paper. Believing this scheme of vast importance, I expect to develop it as rapidly as possible and hope to be able to adapt it to quantitative work. One of the principal advantages of this method is that experiments can be filed away for future reference, and in medico-legal investigations the actual evidence can be carried into court and filed away with other legal documents. I have on hand some experiments made sixteen years ago, in which the majority of the reactions are as distinctly visible as the day they were made.

If you wish to verify the following reactions, first prepare your test papers as follows:

Chemically pure white filtering paper, having a close grain, is dipped in a 10 per cent. solution of ferrocyanide of potassium, laid on a pane of glass and dried in the open air or preferably in a drying oven at 150° F. Then prepare a 10 per cent. solution of neutral chromate of potassium, also one of bromide of potassium and one of hyposulphite of sodium and proceed with each as before.

Having prepared your test papers, rule them off in small squares or otherwise with a lead pencil, and mark each block or space with the symbol of the metal you intend to apply to it. Place your papers on a clean pane of glass, and after once you commence to apply your tests, the paper *must not be moved* until perfectly dry. Take a piece of glass tubing seven inches long and $\frac{1}{4}$ inch inside diameter, draw it out to a point and file off the point, then hold it in the flame, constantly rotating until it forms a perfectly *round* end with an aperture of about $\frac{1}{16}$ inch. A half inch of liquid drawn up into this tube is amply sufficient for 25 different tests.

Dip your tube in the solution to be tested, say potass. sulph., draw up a little of the liquid, wipe off the outside of the tube with a towel and place the tube vertically upon the square marked K, on each one of your test papers; then blow out any liquid remaining in the tube; throw into the larger end of the tube a few drops of distilled water from a wash bottle, and blow it out as before; this will serve to clean the tube, which must be done very carefully before dipping into another solution. Proceed in this way with all the metallic elements. The following are the reactions with ferrocyanide of potassium test paper as I have observed them. I have no doubt many chemists will at once assert that the blue reactions recorded are due to iron as an impurity, but I have as yet been unable to find chemicals that would not give these reactions. These reactions may be due to the acid radical and not to the metal. The peculiar rings and halos are not characteristic of the ferrocyanide of iron.

*K.*—No reaction, white center washing out to a yellowish ring.

*Na.*—No reaction, white center washing out to a yellowish ring.

*$NH_4$.*—White center washing out to a pale blue ring which finally turns green.

*Ba.*—White center washing out to a light yellow ring.

*Sr.*—White center washing out to a thin olive gray ring.

*Ca.*—White center washing out to a pale yellow ring.

*Mg.*—White center washing out to a yellow and finally a citron yellow ring.

*Al.*—A pale blue homogeneous center, surrounded by a white ring, and washing out to a thin greenish ring.

*Cr.*—Pale blue center, surrounded with a pale greenish ring, and a thin green ring and a green halo.

*Zn.*—A homogeneous white spot.

*Mn.*—A very light brown center surrounded by a white ring, and that surrounded by a light yellowish brown ring.

*Ni.*—A gray center, surrounded by a white ring and then by a thin light yellow brown ring.

*Co.*—A dark purple center with rosy purple fringe, surrounded by a thin blue ring, followed by a thicker white ring, followed by another thin blue ring.

*Fe″.*—A sky blue center, surrounded by a paler blue fringe, surrounded by a white ring and then a gray ring.

*Fe‴.*—A dark blue center, surrounded by a navy blue ring, surrounded by a dark blue fringe.

*Ag.*—A reddish brown center with a lighter fringe surrounded by a white ring, surrounded by a citrine ring.

*Hg′.*—A Nile green spot, changing sometimes to a green center and sometimes to a white center. When the center is green, it is surrounded by a white ring and then by a greenish yellow ring; when the center is white, it is surrounded by a broad pale bluish green ring and then a thin greenish yellow ring.

*Pb.*—A very light neutral gray center, surrounded by a broad white ring and a narrow lemon yellow ring.

*Hg″.*—A light pale blue center, surrounded by a white ring, surrounded by a light heliotrope ring, surrounded by a thin citrine colored ring.

*Bi.*—A light blue changing to a sage green center with a whitish edge, surrounded by a bluish gray ring, surrounded by a thin Vandyke brown ring, resembling the margin of a crenate leaf, surrounded by a broad sage green ring and a broad blue halo changing to yellow and vanishing.

*Cu.*—A reddish brown or terra cotta spot, with serrulate margin.

*Cd.*—A pale blue homogeneous center, surrounded by a white ring, surrounded by a thin citrine ring. The margin is entire. Is scarcely distinguishable from *Al*, only that the white ring is not so broad, and on close inspection the outside ring does not have so much greenish east.

*Au.*—A mottled cream and ashes of roses center surrounded by a broad pea green ring, surrounded by a broad old gold colored ring with a distinct undulate margin.

*Pt.*—A whitish green center with deltoid chocolate colored spots in the margin, surrounded by a lemon yellow ring, surrounded by a thread-like old gold colored ring.

*Sn″.*—A pale blue center, surrounded by a broad white ring, surrounded by a distinct thread-like crenate green border, surrounded by a bluish halo.

*Sn⁗.*—A large heliotrope center, surrounded by a light blue halo.

*Sb.*—A dark blue center, irregular margin, surrounded by a light blue ring, surrounded by a distinct thread-like greenish ring, surrounded by a very large light blue halo, its diameter being three or four times the diameter of the dark blue center.

*As‴.*—At first a delicate flesh color, changing to white, surrounded by a thin yellow ring.

*As⁗.*—At first a delicate salmon, changing rapidly to white, surrounded by a thin yellow ring.

REACTIONS WITH NEUTRAL CHROMATE OF POTASSIUM.

*K.*—A white center, surrounded by a broad pale yellow ring and a raised thin yellow ring.

*Na.*—A white center, surrounded by a scarcely perceptible yellow ring.

*$NH_4$.*—An indistinct white center, surrounded by a broad pale yellow ring, surrounded by a broad orange yellow ring.

*Ba.*—A pale yellow center, surrounded by a distinct white ring, surrounded by a broad yellow ring.

*Sr.*—A white center, surrounded by an indistinct yellow ring.

*Ca.*—A white center, surrounded by distinct salmon yellow ring.

*Mg.*—A white center, surrounded by a lemon yellow ring.

*Al.*—A peculiar very light lavender gray colored center, surrounded by an orange yellow ring, then by a yellow ring and a raised thin sulphur yellow ring.

*Cr.*—A brownish lavender center, surrounded with a pure lavender ring, surrounded by a thin, serrated garnet ring with a thin orange yellow margin.—*Pharmaceutical Record.*

## NOTES ON ESSENTIAL OILS.*

*Angelica Oil.*—A parcel of angelica root has been received from Japan, though too recently to allow of a report upon the essential oil distilled from it. Eight species of *Angelica* are known to occur in Japan, but the exact botanical origin of the present consignment is not yet ascertained.

*Arnica Flowers Oil.*—It is stated that 100 kilos of fresh arnica flowers yield only about 40 grammes of essential oil.

*Arnica Root Oil.*—In order to afford pharmacists an opportunity of examining this oil more closely, Messrs. Schimmel have distilled a quantity of fresh arnica root and have at their disposal about a kilogramme of the pure essential oil, which they are willing to supply at cost price for the purpose of scientific investigation.

*Bay Oil.*—In respect to this oil, the demand for

* From Messrs. Schimmel's report.

which is said to be still increasing, Messrs. Schimmel confirm from their experience the statements made recently as to the incorrectness of the description of its specific gravity and solubility, as given in the United States Pharmacopœia. Oil distilled in their New York factory from imported leaves had a specific gravity of 0·9828 at 15° C.

*Betel Leaves Oil.*—Samples of this oil have been supplied with a view to experiments being made as to its therapeutic properties.

*Calamus Oil.*—A sample parcel of calamus root has been received from Japan, the oil distilled from which will be described in the next report.

*Camphor Oil.*—The "light camphor oil," being the portion of the crude oil boiling at about 175° C., is said to be now in regular demand for various technical industries. Recently it has found practical use in the soap manufacture, it having the property of covering the penetrating, disagreeable odor of ordinary kinds of fat and tallow, and also the acrid odor of bone fat extracted by means of benzene. For this purpose the light camphor oil may be mixed with the fat before or after saponification, about 2 or 3 kilos being required for 100 kilos of soap. It is also said to be used by varnish makers, sometimes alone and sometimes mixed with turpentine oil. In a previous report the opinion was expressed that "light camphor oil" contained terpineol, but, though this is still thought probable, that body has not yet been isolated; on the other hand, it has been found to contain from 5 to 6 per cent. of cineol (eucalyptol).

*Cananga Oil.*—Messrs. Schimmel refer to a second, low-priced, variety of Indian cananga oil as being suitable as a perfume for soaps, but devoid of the finer fragrance that characterizes the prime quality Indian cananga oil and, in a greater degree, the ylang-ylang oil.

*Eucalyptus Oil.*—It will be remembered that in previous reports Messrs. Schimmel have controverted the presence of eucalyptol in the oil distilled from *Eucalyptus amygdalina*, the source of most of the eucalyptus oil received from Australia, but that recently Herr Gildemeister reported that by a more delicate reaction he had obtained that body from amygdalina oil (see before, Sept. 1, p. 164). Referring to this subject, Messrs. Schimmel quote from a published statement by Mr. Staiger, the Brisbane chemist, a passage to the effect that in Australia it frequently happens that in the distillation of eucalyptus oil the leaves of both species, *E. globulus* and *E. amygdalina*, are placed in the still, from which is inferred the possibility of considerable variation in commercial oil of *E. amygdalina*. Consequently, the opinion is expressed that the question as to the presence of eucalyptol will not have been definitely settled until an examination has been made of a sample of a pure oil specially distilled from *E. amygdalina* leaves, and this investigation the firm proposes to undertake. Messrs. Schimmel state that they themselves have recognized the presence of eucalyptol in commercial amygdalina oil, but that the quantity is too small and the process too difficult to pay for its separation. The "so-called eucalyptol from *E. amygdalina*, which by this time may be looked upon as practically killed," obtained by fractional distillation over caustic potash, is said to consist principally of phellandren, $C_{10}H_{16}$ (eucalypten), and about 20 per cent. of eucalyptol, $C_{10}H_{18}O$. Such a preparation has a specific gravity of 0·890, is strongly lævogyre, and does not solidify in a freezing mixture. It can be easily identified by mixing 1 c. c. of the oil with 2 c. c. of glacial acetic acid, and adding to the mixture 1 to 2 c. c. of a concentrated aqueous solution of sodium nitrite, when a gentle shaking causes almost instant solidification to a crystalline paste of phellandren nitrite. Neither pure eucalyptol nor oil of *E. globulus* gives this reaction, both remaining unaltered, or at most becoming somewhat darker in color.

Larger consignments have now been received from Australia of the leaves of *Eucalyptus maculata*, var. *citriodora*, *Backhousia citriodora*, and *E. staigeriana*, which have been distilled. The oil obtained from the leaves of *E. maculata*, var. *citriodora*, is described as corresponding in its characters with the sample mentioned in the April report (see *Pharm. Journ.*, vol. xviii., p. 908). The principal constituent of the oil is a ketone (? aldehyd), which gives with acid sulphites of the alkalies a difficultly soluble compound. It boils under slight decomposition between 205° and 210° C., and is identical with the ketone (aldehyd) occurring in citronelle oil, which according to Kremers has the composition $C_7H_{14}O$, though the analyses made by Messrs. Schimmel correspond more closely to $C_7H_{12}O$. About a kilogramme of this body, which it is proposed to call "citronellon," is available for investigation. The oil from the leaves of *Backhousia citriodora* corresponds also with those attributed to it in a previous report (loc. cit.). The aldehyd or ketone-like body there spoken of as its principal constituent has been more closely examined. It has a composition represented by the formula $C_{10}H_{18}O$, boils at 220°–227° C., undergoes decomposition in distillation, and easily resinifies. This body, which has been named "citral," possesses an intense lemon odor and has been found also in small quantity in lemon oil and lemon grass oil, while it constitutes 30 per cent. of oil distilled from "citronelle fruit."

*Ginger Oil.*—The use of ginger oil is said to show a considerable falling off, the spirituous extract of the rhizome being preferred for liqueurs. The specially prepared ginger from China referred to in a previous report (see vol. xviii., p. 888) has also proved unsuitable and much too dear for the liqueur manufacture.

*Kesso Root Oil.*—A first consignment of kesso root or Japanese valerian root (*Patrinia scabiosæfolia*) has been received, and the oil distilled from it is now available.

*Lavender Oil.*—Messrs. Schimmel criticise some published descriptions of lavender oil and give the following as the character of what they would consider to be a genuine sample. Specific gravity: 0·895 at 15° C., 0·880 at 20° C. Solubility: 1 part in 8 parts of alcohol, sp. gr. 0·864. Distillation: Out of 100 c. c. below 160° C. none passes over; from 165°–190°, 6·5 c. c.; from 190° to 200°, 78·5 c. c.; total below 250° C., 85 c. c.

*Cochlearia Oil.*—Messrs. Schimmel express the opinion that a genuine distillate of scurvy grass (*Cochlearia officinalis*) is not to be met with in commerce, and say that it could only be produced at enormous cost, since the fresh herb only contains ¼ to ⅓ per 1000 of essential oil. A mixture of oil of rue with some mustard oil is sold under the name in Germany, which has not the slightest resemblance to the genuine article. Scurvy-grass oil contains as its principal constituent, according to Hofmann, a fraction boiling at 161°–165° C., sp. gr. 0·944, which he has recognized as isobutyl mustard oil and prepared synthetically. Experiments made by Messrs. Schimmel, however, to obtain in this way an artificial scurvy-grass oil have been fruitless, since, although the commercial isobutylsulphocyanate has a certain resemblance to the genuine distillate, it cannot be used as a substitute on account of a highly objectionable odor accompanying it.

*Sumbul Oil.*—Referring to the difficulty in obtaining supplies of sumbul root for the distillation of this oil, the report states that this drug is not now to be met with in Russia. Formerly it was brought by merchants from Buchara, Turkestan, to the fair at Nischnei-Novogorod, but for some years past, on account of the absence of demand for it, the supply there has ceased.

*Rosemary Oil.*—The following are given as the characters of an undoubtedly pure Italian oil of rosemary, obtained first hand: Specific gravity: 0·905 at 15° C., 0·900 at 20° C. Solubility: 1 part in 12 parts of alcohol, sp. gr. 0·864, as a maximum, showing already a trace of turbidity. Distillation: Out of 100 c. c. there passes over up to 170° C., 4·5 c. c.; from 170°–200° C., 84 c. c.; total up to 200° C., 88·5 c. c.

*Mustard Oil.*—In correction of some statements that have been made recently as to the amount of sulphuretted oil obtainable from certain cruciferous seeds, Messrs. Schimmel say that the maximum quantity of oil yielded by *Brassica nigra* (Dutch mustard) is 0·90 per cent. and by *Sinapis juncea* (Russian mustard), 0·52 per cent.

*Storax Oil.*—The residue after the distillation of the oil from *Styrax liquida* is said to be practically odorless.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